National Park Service
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Natural Resources Program Center

National Capital Region Network Long-Term Forest Vegetation Monitoring Protocol

Version 2.0 (May, 2009)

Natural Resource Report NPS/NCRN/NRR—2009/113

ON THE COVER
J. Parrish measures the diameter of a tree in Prince William Forest Park.
Photograph by: Thomas Paradis, NPS.

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John Paul Schmit
Geoff Sanders
Mark Lehman
Thomas Paradis

National Park Service
Center for Urban Ecology
4598 MacArthur Blvd., NW
Washington DC 20007

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Executive Summary

The vital sign selection process of the NPS Inventory and Monitoring Program (I&M) identified forest vegetation monitoring as a critical need for the parks of the National Capital Region Network (NCRN). The data collected using this protocol will provide much needed baseline information on the forests in the NCRN, particularly in terms of community structure and composition. The information will also be used to determine long term trends in community composition, and in the abundance and distribution of individual species.

Additionally, there are several short- and long-term threats to the forests found in the NCRN parks. There is evidence that the parks are overpopulated with deer (also the focus of a vital sign), which poses the risk of unsustainable browsing pressure on forest ecosystems. In particular, over-browsing can lead to the loss of understory species and reduce or eliminate regeneration of some tree species. Invasive exotic plant species are found throughout the network parks and may out-compete native vegetation. Several tree species are highly susceptible to insect pests and pathogens. Long-term threats include changes in land use inside and outside the parks, long-term climate change, pathogens and air pollution.

This protocol includes monitoring of three related vital signs: forest vegetation condition, invasive species and forest pests and pathogens. The protocol is based on the plot design of the US Forest Service Forest Inventory and Analysis program and the results of a 2004 pilot study. Thirteen standard operating procedures (SOPs) document the methods used to collect the relevant data. The protocol was developed in consultation with other I&M networks in the eastern US so that the data collected will be compatible with that of other networks to provide a wider context for trends in the NCRN parks.

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Background and Objectives

Background and History

This protocol is designed for monitoring forest vegetation in eleven parks within the National Park Service's National Capital Region Network (NCRN) in the Washington, DC, metropolitan area. These parks are Antietam National Battlefield, Catoctin Mountain Park, Chesapeake and Ohio Canal National Historical Park, George Washington Memorial Parkway, Harpers Ferry National Historical Park, Manassas Battlefield Park, Monocacy National Battlefield, National Capital Parks-East, Prince William Forest Park, Rock Creek Park, and Wolf Trap National Park for the Performing Arts. It should be noted that National Capital Parks East is not an individual park, but rather an administrative unit that manages a large number of mostly small parks (Anacostia Park, Greenbelt Park, Fort Circle Parks, Ft. Washington Park, Piscataway Park, etc.).

Forests are the dominant natural vegetative community in the NCRN parks. While some parks have individual monitoring programs focused on specific threats, others have no forest monitoring in place, and there is no standardization among the existing park programs. The data collected using this protocol will provide much needed baseline information on the forests in the NCRN, particularly in terms of community structure and composition. The information will also be used to determine long term trends in community composition, as well as trends in the abundance and distribution of individual species.

Forests in the NCRN parks are currently facing several threats. The most severe of these include high browsing pressure from deer, invasion by exotic plant species, decline of tree species such as hemlocks and dogwoods due to pathogens, and changes in land use. Collectively these threats have the potential to cause drastic changes in vegetation structure, species dominance and composition, and resources available to non-plant species.

Development of forest monitoring field procedures has been a joint effort between National Capital Region Network Inventory and Monitoring staff and USDA Forest Service Forest Inventory Research, including subcontractors. An initial protocol was developed in 2004. In 2005 the protocol was revised to more closely correspond to FIA standards and to be consistent with the staffing resources of the NCRN and the needs of the parks (Schmit et al., 2006). Much of the early development and protocol writing was performed by David Chojnacky of the US Forest Service and Mikaila Milton of the National Park Service. Identification of monitoring locations began in 2005. In 2006 protocol version 1.0 was implemented and 100 plots were monitored. In 2007 and 2008 monitoring continued and 100 new plots were measured each year. Protocol version 2.0 was written in 2008 with an updated format and expanded rationale for many of the measurements in the SOPs. No changes were made to the actual methods in the SOPSs. Data from version 2.0 is fully compatible with version 1.0. The NCRN is currently evaluating the benefits of adding one or more soil monitoring SOPs to complement forest condition monitoring. If soil monitoring is adopted, the protocol will be updated.

Rationale for Monitoring this Resource

Forests are the dominant natural vegetation cover for the parks in the NCRN and a wide variety of forest communities are found inside park boundaries. Most of the parks in the NCRN have a specific mandate related to management of forests in their founding legislation. These include requirements to preserve natural forests, to preserve or recreate historic conditions related to Civil War battles, to protect watersheds, to provide recreation and to protect scenic vistas (National Park Service, 2005a). As of 2008, no completed vegetation maps of the parks exist, except for Rock Creek Park, but vegetation mapping is underway as one of the basic inventories of the I&M program and should be completed by 2011.

In 2002 The Science Advisory Committee to the NCRN selected the "vital signs" for the network. The vital signs are indicators that are targets for long term monitoring. They were selected based on their importance for documenting and understanding changes in the parks' natural resources (National Park Service, 2005a). Many of the vital signs are directly or indirectly related to forest vegetation, including: forest vegetation condition, invasive plant species, forest pests and pathogens, changes in land cover and land use, density of white-tailed deer and forest breeding birds.

Of the six vital signs listed above, forest vegetation condition and forest breeding birds examine the resources of concern. The other four vital signs: pests and pathogens, exotic plant species, land cover/land use, and white-tailed deer density are all threats to the resources that are expected to persist for the foreseeable future. Although white-tailed deer are a native species, the concern is overpopulation and its effects rather than loss of deer. When the data from these protocols is combined it will help to determine how serious the various threats are and to what extent the natural resources of the parks are being impacted (Figure 1).

This protocol describes the methodology for collecting data for the forest vegetation, exotic plant and forest pest and pathogen vital signs. Data for these vital signs are collected from randomly placed monitoring plots. Methods for monitoring white-tailed deer density, forest birds, and changes in land cover and land use are described in separate protocols (Bates, 2006; Dawson and Efford, 2006; Townsend et al., 2006). Monitoring points for forest birds are co-located, when possible, with the forest vegetation plots described in this protocol. Deer density and land cover/land use measurements are not co-located with these plots, but rather collected for each park as a whole.

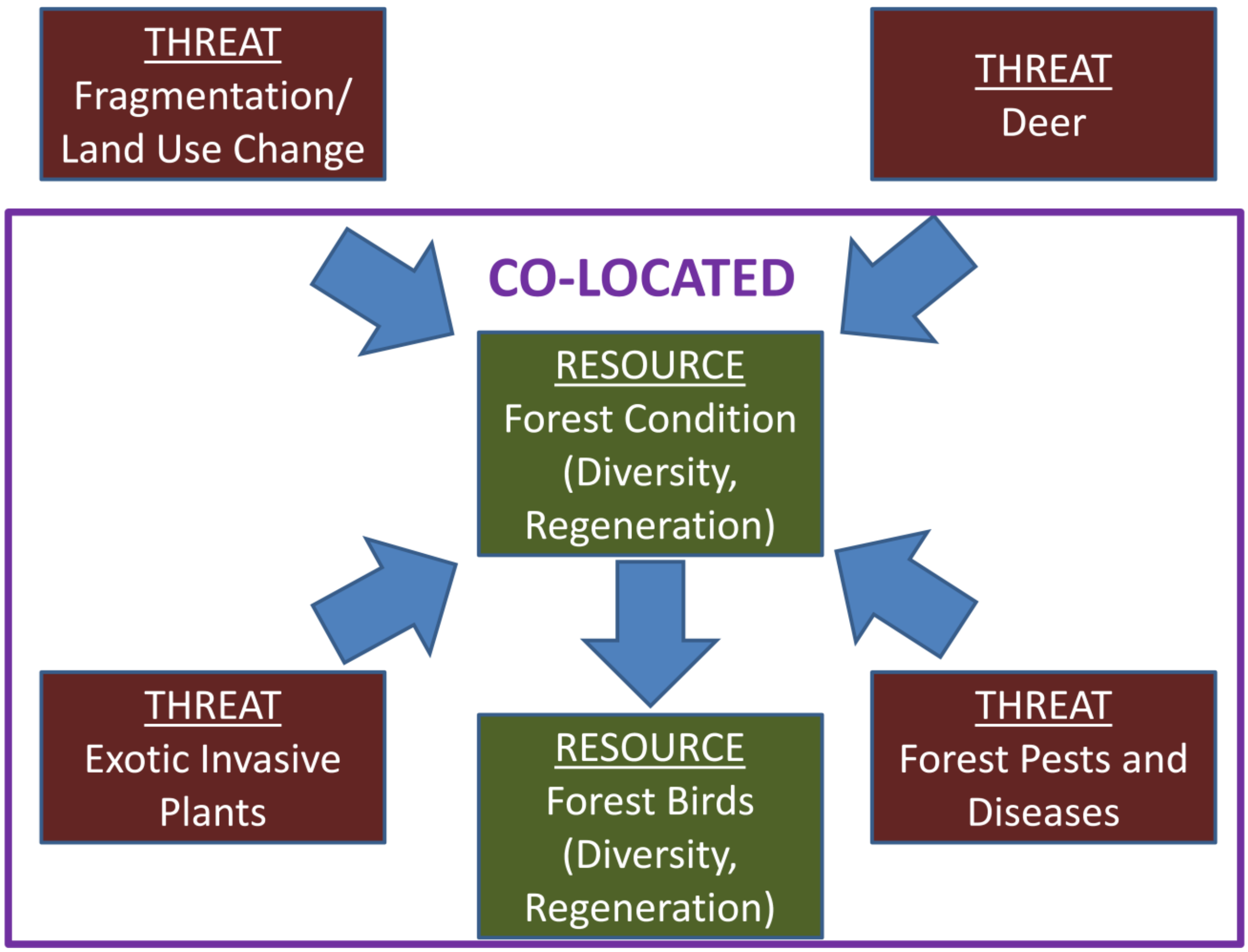

Figure 1. Relationship of forest vital signs. The four vital signs within the purple box are monitored at the same sample locations. Deer and land use change are monitored on a park wide basis.

Measurable Objectives

The purpose of this protocol is to monitor changes in forest composition in the NCRN parks. In selecting objectives, emphasis was placed on those indicators that are likely to respond to known forest threats, are important for other species in the forest ecosystem, and are likely to be useful in assessing future threats. These selection criteria have resulted in the following measurable objectives.

The NCRN will document status and long term trends in:

1. Tree and shrub distribution, composition and richness: Deer browse, exotic plants, and pathogens all have the potential to impact some plant species more than others. Monitoring species composition will allow the NCRN to identify individual species which have a changing geographic range throughout the region. This will be an effective means of monitoring species which tend not to be very abundant in individual plots, but are present in many plots. Locations or forest types which are particularly species rich or

contain rare species can also be identified and may merit special management consideration. All tree and shrub species will be monitored.

2. Tree and shrub basal area and abundance: Basal area is a measure related to the total woody biomass of a forest stand. Large declines in basal area are indicative of a major disturbance in the forest ecosystem. If these declines were widespread and not part of natural disturbance processes they could have a significant negative impact on all other forest species. Abundance and basal area of individual tree and shrub species will allow the NCRN to determine if individual species are declining or increasing region-wide. This will be particularly useful for species which are found in many plots and tend to be abundant in those plots.
3. Amount of coarse woody debris per plot: Coarse woody debris is an important habitat for many animal and microbial species. Declines in the amount of coarse woody debris could negatively impact a wide variety of other species.
4. Distribution, abundance and basal area of exotic trees and shrubs: This will allow the NCRN to determine if exotic trees and shrubs are becoming more common and to determine what changes in forest vegetation condition are associated with these exotic species.
5. Exotic understory plant distribution and cover. Exotic plants may be able to out-compete native understory plants. By monitoring the distribution of understory plants the NCRN will be able to determine which plants are spreading throughout the region. The NCRN will monitor the cover of exotic plants to determine how large of an impact they are having in the plots where they occur. The NCRN will work with the regional Exotic Plant Management Team and the Invasive Species Coordinator to determine which plants should be monitored. The list is updated annually as new plant species invade network parks.
6. Vines on trees: The NCRN will identify all vine species growing on each tree, including exotic vines, and determine which trees have vines growing in the crown. This will allow us to determine if invasive vines are spreading and if trees that have vines have a higher mortality rate that those without vines.
7. Presence of select forest pests and diseases: The NCRN will record the presence of select forest pests and diseases on trees. The NCRN will work with the regional Integrated Pest Management Coordinator to determine which pests and diseases should be monitored. We will focus on those which are particularly destructive. By tracking the survival of infected trees, the NCRN will determine if these pests and diseases are causing significant tree mortality in network parks.

The data from forest monitoring will be examined at both the park-wide and region-wide scales. As data accumulates, the NCRN plans to compare results with other I&M networks and with FIA data. This will allow the NCRN to determine if changes seen in the network are comparable to those seen elsewhere.

Sampling Design

Sampling Design Rationale

In designing the vegetation monitoring program, it was decided to use the US Forest Service, Forest Inventory and Analysis program as a model (FIA, 2004). Other possibilities included developing a custom protocol for the NCRN or adopting a different standard such as the North Carolina Vegetation Survey protocol (Peet et al., 1998). It was decided not to develop a new protocol as adequate protocols already exist. These protocols cover existing NCRN measurable objectives and have SOPs for other indicators that the NCRN could choose to use in the future. Furthermore, adopting a widely-used protocol would allow us to take advantage of datasets collected from forests near the NCRN parks. The FIA protocol is used by the Forest Service nationwide and includes an FIA plot in Catoctin Mountain Park. Furthermore, based on informal discussion it was clear that the FIA protocol was going to be the basis for forest vegetation monitoring by other eastern I&M networks. Therefore, FIA was chosen in order to maximize the benefits of data sharing.

While FIA is the basis of the NCRN protocol there are some differences. Not all of the data collected on FIA plots will be collected on NCRN plots. NCRN plots have the same area, but a different layout than FIA plots (see SOP 2). For tree monitoring, all of the NCRN data is collected on a large plot, whereas FIA data is collected on several subplots in close proximity. Some additional minor changes were made between FIA measurements and those in the NCRN protocol. These changes are discussed in the individual SOP's.

Site Selection

In 2005, the NCRN developed a network-wide, 250 meter square grid across the network parks. The grid exists as a spatial dataset in the GIS system. Points defined by intersections of the grid are potential monitoring locations. Those locations that are actually being monitored are marked in the field as indicated in SOP 2.

The purpose of this grid is to establish a consistent basis for sampling that will allow the NCRN to co-locate sampling sites and integrate results from a variety of monitoring protocols. The grid is currently used in the forest bird monitoring and may be used in additional protocols or research projects if warranted. Two-hundred fifty meters was chosen as a grid size as many NCRN parks have long narrow forests (e.g., C&O Canal, Baltimore-Washington Parkway, George Washington Memorial Parkway) that would be missed with a larger grid. A smaller grid was not used in order to ensure that data collected at one point on the grid would be independent from data collected at an adjacent point on the grid. The NCRN forest bird monitoring relies on audible point count data (i.e. listening for bird calls). Point counts closer than 250m apart run the risk of counting a single bird in two listening points, even if the bird stays in the same location. Each point on the grid on park owned land can be considered a potential sampling location for forest vegetation monitoring.

A randomized procedure was used to choose which of the grid points would actually be used for forest monitoring. Sampling locations were selected by using generalized random-tessellation stratified survey (GRTS: Stevens and Olsen, 2004). GRTS was chosen over simple random sampling as GRTS creates a random sample that is spatially balanced – points are not clumped in a single part of the study area.

Stratification based on vegetation or landscape features has not been incorporated. Stratification by forest type has been shown to be problematic, as vegetation types change quickly. This complicates analysis and defeats the purpose of the original stratification (Diefenbach and Mahan, 2002). Furthermore, detailed vegetation maps were not available for the NCRN parks when monitoring began. An alternative to stratification by vegetation type would be to stratify based on a more permanent feature of the landscape such as slope or aspect but this was rejected. It is not known what responses the current major threats (deer, exotic invasive plants, diseases) would have to these features, which would reduce the benefits of stratification and complicate future analysis. Finally, after the data has been collected it could still be analyzed to determine if changes in forest structure are related to landscape features.

Similarly, it was decided that the sampling would not be stratified by park, that is, there would not be a predetermined number of sites in each park. Rather the monitoring locations are randomly placed across the entire network and parks with more forested area have more monitoring plots. This was chosen as the NCRN parks are not 11 distinct and compact park units. Parks in the NCRN, particularly in the DC region, are fragmented and intermingled. Parts of Rock Creek are contiguous with the C&O Canal, parts of George Washington Memorial Parkway are surrounded by the C&O Canal and the border between the small forest fragments managed by Rock Creek and by National Capital Parks East is an arbitrary line drawn for administrative convenience. Outside of DC, Harpers Ferry is bisected by the C&O Canal. Additionally, George Washington Memorial Parkway and the C&O Canal are long linear parks, so forest conditions at one end of the park may differ markedly from those at the other end. All of these considerations would reduce the benefits of stratification by park, as we may wish to analyze the data by a group of neighboring parks, or break longer parks into smaller regions. These types of analysis can be done post hoc if we select all of our sampling sites from a regional design.

GRTS was used to generate a list frame (potential sampling locations) for forest monitoring that includes all points on the grid that fall within NCRN parks. The list frame was then used to pick the actual monitoring locations. Each point in the list frame is numbered in the order in which they should be considered for monitoring. Prior to plot setup, potential monitoring points were visited to determine suitability for forest vegetation monitoring (SOP1). A point was eliminated if it did not contain forest vegetation (on a road, waterway, maintained field, etc.), was on a slope greater than 30°, or was otherwise hazardous, and the next point on the list was considered. Once a preliminary list of monitoring points was developed it was submitted to the various parks. The parks could then veto points if there were concerns about monitoring due to the presence of archeological or cultural resources, interference with visitors, or any other concern. As of 2009, only two points have been vetoed by a park, in both cases due to the fact that the monitoring plots would be in very high visitor use locations.

For panel design (see below) each panel of 100 sites is constructed by taking the first 100 suitable sites from the list for the first panel, the second 100 suitable sites for the second panel and so on. If a site becomes unusable at some point in the future (e.g. land is transferred out of the park system, forests are felled for visitor facilities etc), then the next suitable unused point on the GRTS list will be used as a replacement.

Sampling Frequency and Replication

Forest monitoring will take place annually but not all plots will be measured every year. Yearly measurements of plots can cause soil compaction and trampling of the understory which would bias the monitoring results. Therefore, plots will be sampled on a rotating panel design, with four panels. Each year a panel is sampled. Sampling will take place from May through October, when foliage is fully developed.

Consideration was given to a sampling design with overlapping panels – one where a small subset of plots would be measured two years in a row. The advantage of an overlapping panel design is that it can give the investigator an estimate of trends on a yearly basis rather than waiting several years until a panel is re-sampled. Despite this advantage, this type of design was ultimately rejected. It was felt that to detect an annual change with a small sample size, the change had to be large in magnitude. Furthermore, annual variation had to be fairly low, as a high standard deviation would make it difficult to detect any changes. Few if any of our measures were likely to have both a large trend and small deviation. Furthermore, given the choice of possibly detecting an annual trend in some measures vs. establishing a greater number of plots, we felt that the parks would be better served by a larger sample size overall. Finally, sampling the same plot in successive years would increase trampling on the plot.

Recommended Number and Location of Sampling Sites and Frequency of Sampling

The NCRN has decided to sample 400 plots in total. The plots are divided into four panels of 100 plots each. One panel will be sampled per year, so that each plot is sampled once every four years.

A preliminary power analysis indicated that at least 300 plots should be monitored, 75 each year. That would allow the NCRN to detect large changes in moderately abundant species and smaller changes in dominant species after the first re-measurement of the plots. During the first year of monitoring NCRN staff determined that at least 100 plots could be monitored annually. It was decided to increase the sampling size to 400 plots rather than sample 300 plots on a 3 year panel.

Level of Change That Can Be Detected

The data from the first three years of the monitoring was used for a power analysis. The analysis is preliminary as it does not have repeated measures of the same plots, so spatial variation is used as a stand-in for variation over time. It is likely that the variation over time will be less than that across space, which makes this a conservative estimate of the statistical power of this study.

A sample size analysis is used to determine the sample size needed to determine a set level of change at a particular power and alpha level. Performing this analysis for the forest monitoring protocols presents some challenges. Multiple measurements will be taken on each plot, so a design that provides an adequate sample size for some measurements may not be adequate for others. Additionally, as the monitoring is expected to continue indefinitely, more data will be added and the power to detect change will increase. A design that does not provide adequate power after the first repetition of the panels may provide adequate power after several repetitions.

For this analysis it was decided that we would examine the power of the monitoring effort to determine changes between the first two complete rounds of monitoring. Any analysis that has sufficient power to detect changes between two rounds will also have sufficient power over multiple rounds. As more data becomes available, the power analysis can be updated to reflect the greater power of multi-round sampling.

Measurable Objective 1 – Tree and Shrub Distribution

Tree and shrub distribution will be measured as the proportion of plots that each species occupies. Trends in this proportion will indicate which species are spreading in the region and which are becoming less common.

A power analysis for this objective is somewhat difficult. Each plot will only be visited once per sampling cycle. As we will not have multiple samples of each plot, we cannot use occupancy estimation analysis (MacKenzie et al., 2006). A more appropriate test would be the "McNemar test for significance of changes" (Conover, 1999). The McNemar test is a variant of the sign test that determines if there was a significant difference between the number of unoccupied plots that are colonized and the number of plots occupied by the species that become vacant. If more unoccupied plots are colonized then the species is spreading, and if more occupied plots become vacant then the species is declining. Unfortunately, the power of the test is dependent on the number of plots that change between occupied and vacant. Without a reliable estimate of this number, it is not possible to perform a meaningful power analysis.

For the purposes of this protocol, a power analysis will be performed assuming that the data will be analyzed as a test for differences in two proportions. This test compares the proportion of plots occupied by each species after each complete sampling cycle. This test does not take into account that plots that are occupied by a species in one sampling cycle are more likely to be occupied by that species in subsequent rounds of sampling. Therefore, the power analysis for this objective should be considered preliminary and will be updated when appropriate data are available.

In general, the test for a differences between two proportions is valid when the sample size (n) and the proportion of occupied sites (p) meet the criteria that

$n * p \geq 10$

and

$n(1 - p) \geq 10.$

Given the 400 plot sample size at the regional level, this test will be valid for species that occupy between 2.5% and 97.5% of all plots. For a difference between two proportions test, differences are most difficult to detect when one of the proportions is 0.5 (Moore and McCabe, 1993).

When this occurs we will be able to detect differences of 9.8% with power =0.8 and p=0.05 (Table 1).

Park level analysis will be possible in some cases. Fifty eight plots are required in order to detect a change from 0.5 to 0.25 or 0.75 with a power = 0.8 and p =0.05. At least two of the parks, Prince William and the C&O Canal, will have more than 58 plots.

Unlike trees which are measured on one large plot, saplings and shrubs are monitored on 3 microplots within each plot. This data can be analyzed using occupancy analysis (MacKenzie et al., 2006). In this analysis, each of the microplots will be treated as a separate "visit" that samples the plots for each sapling and shrub. Occupancy analysis determines the proportion of plots that are occupied by each of the species (ψ) and the detectability of each species. The detectability is a measure of how likely we are to find a species in our microplots if it is present in the plot.

Given an estimate of the occupancy and detectability of a species it is possible to do a power analysis. An analysis was performed on the power of the design to determine the occupancy of saplings and shrubs that were present in at least 10% of the 300 plots sampled as of September 2008. Eight species met this criterion. At a minimum, across the entire 400 plots, the design should have a standard error of less than 0.05. All but one species met this criterion by wide margins (Table 2).

Measurable Objective 2 – Tree and Shrub Basal Area and Density

Tree and shrub basal area and density will be analyzed by looking at plot totals across all species, and by looking at data from individual species. Regardless of the focus of the analysis, at a minimum, after one resampling of the plots, the design should have a power of 0.80 to detect a 50% change in the measurement of interest with an alpha of 0.05.

For data summed across all species, an appropriate test is a matched t-test that compares density or basal area from one round of sampling to the next. A power analysis for this test was performed using the power for a one sample t-test. For overall tree density and basal area, 8 plots are needed to detect a 50% change from current levels. With 400 plots a 5.9% change in basal area and 5.5% change in density can be detected (Table 1)

For data from individual species, the situation in considerably more complicated. Each individual species is present in less than half the plots. As a consequence, the distribution of basal area or density has a large peak at zero. In general this is often referred to as a "zero-inflated distribution" There is a variety of zero-inflated models. The one that may best fit this data is a "tweedie distribution", part of a family of distributions known as "exponential dispersion models" (Dunn and White, 2005). These models are used in fitting generalized linear models. Using the tweedie distribution (available in the R statistical package) generalized linear models can be used to model changes in density and basal area of trees, shrubs and saplings over time (Figure 2). Unfortunately, a power analysis is not readily available for this type of modeling.

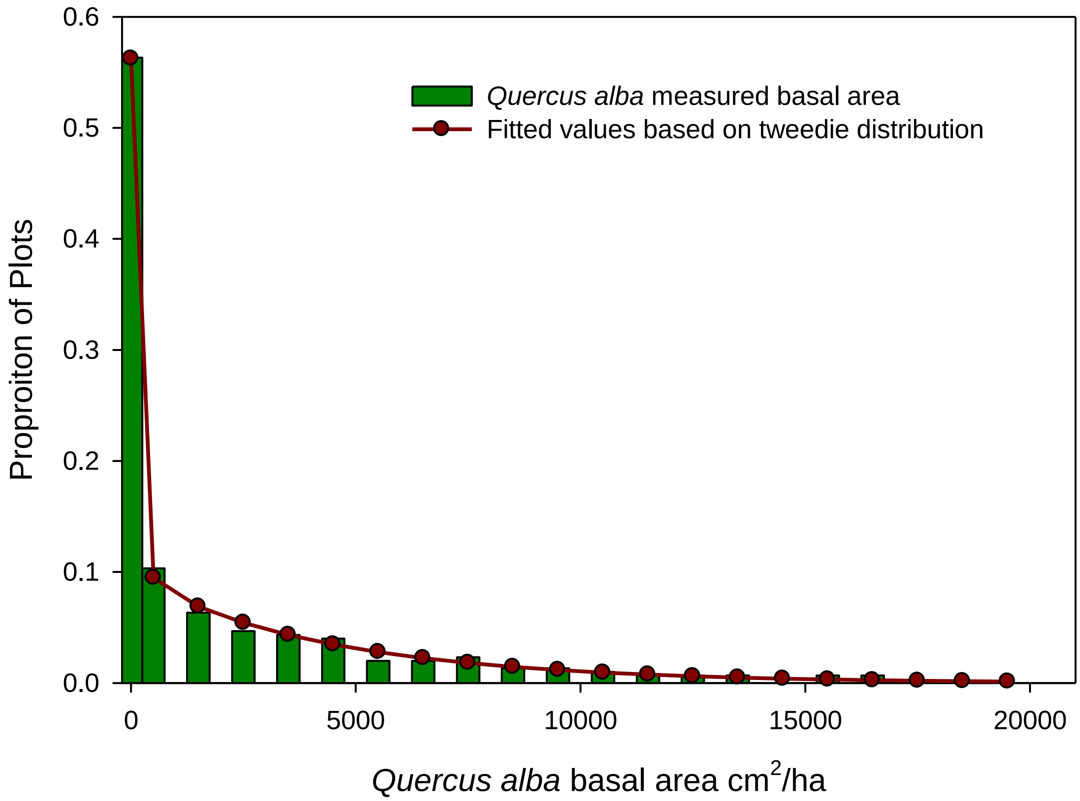

Figure 2. *Quercus alba* measured basal area vs. fitted values based on tweedie distribution. The data from the monitoring plots shows a large proportion of the plots have no *Quercus alba*. This can be accounted for by modeling the data as a tweedie distribution.

Measurable Objective 3 – Coarse Woody Debris

The density of coarse woody debris, measured in m^3/ha, will be analyzed by determining the values on each plot by combining data from the three transects. This data in not normally distributed, but a $\log_{10}$ transformation better approximates a normal distribution. A power analysis was performed on the transformed data using a one sample t-test as was done for total tree basal area and density in Measurable Objective 2. The analysis indicated that 18 plots are needed to detect a 50% change from current levels, and that with 400 plots a 9.8% change in the $\log_{10}$ transformed data can be detected (Table 1). Due to the use of the logarithmic scale, the amount of change that can be detected in untransformed values depends upon the amount of CWD present. Smaller changes can be detected when smaller amounts of CWD are present to begin with.

Measurable Objective 4 – Exotic Tree and Shrub Distribution, Basal Area and Density

Distribution for exotic trees will be analyzed in an identical manner as that for native trees, as outlined in Measureable Objective 1 above. Basal area and density of exotic trees will be analyzed as described in objective 2 above.

Table 1. Power analysis results for parametric tests.

Measurement	Test	Mean	SD	Change Detectable at Power =0.80	% Change Detectable	Minimum Plots Desired
Tree/shrub species distribution	2 proportions	0.5	na	0.098	19.6%	58
Total tree basal area per plot (cm^2/ha)	1 sample t-test	276,000	109,000	15,300	5.5%	8
Total tree density per plot (individuals/ha)	1 sample t-test	386	163	22.9	5.9%	8
Coarse woody debris [$Log_{10}(m^3/ha)$]	1 sample t-test	1.36	0.945	0.133	9.8%	18
Gypsy moth increase in distribution	2 proportions	0.13	na	+0.074	56.7%	505
Gypsy moth decrease in distribution	2 proportions	0.13	na	-0.059	45.7%	326

Measurable Objective 5 – Exotic Understory Plant Distribution and Cover.

One measure of the impact of exotic understory plants is how commonly they occur across the region. As with trees, increases or decreases in the number of plots occupied can be used to track the distribution of the species.

Exotic herbaceous plants are measured on twelve 1 m^2 quadrats in each plot. Like the data for shrubs and saplings, the exotic herbaceous data can be analyzed using occupancy analysis (MacKenzie et al., 2006). In this analysis, each of the quadrats will be treated as a separate “visit” that samples the plots for each of the targeted species.

An analysis was performed on the power of the design to determine the occupancy of exotic species that were present in at least 5% of the 300 sampled plots. Nine species met this criterion. At a minimum, across the entire 400 plots, the design should have a standard error of less than 0.05. All nine species met this criterion by wide margins (Table 2).

Table 2. Power analysis of occupancy data.

Species	Common Name	Measured as:	Naïve ψ[1]	Detectability[2]	Corrected ψ[3]	SE[4] w/ 400 plots	Plots needed for 0.05 SE[4]
Acer rubrum	red maple	sapling	0.31	0.27	0.51	0.058	543
Asimina triloba	pawpaw	sapling	0.13	0.44	0.16	0.023	82
Cornus florida	flowering dogwood	sapling	0.17	0.25	0.29	0.050	396
Fagus grandifolia	American beech	sapling	0.37	0.61	0.40	0.026	107
Ilex opaca	American holly	sapling	0.18	0.49	0.20	0.023	86
Nyssa sylvatica	blackgum	sapling	0.32	0.39	0.41	0.036	208
Kalmia latifolia	mountain laurel	shrub	0.15	0.51	0.17	0.021	72
Lindera benzoin	northern spicebush	shrub	0.20	0.74	0.20	0.020	66
Alliaria petiolata	garlic mustard	herbaceous	0.29	0.56	0.29	0.023	83
Berberis thunbergii	Japanese barberry	herbaceous	0.087	0.18	0.096	0.015	41
Celastrus orbiculatus	oriental bittersweet	herbaceous	0.087	0.28	0.088	0.014	33
Duchesnea indica	India mock strawberry	herbaceous	0.15	0.33	0.15	0.018	52
Glechoma hederacea	ground ivy	herbaceous	0.07	0.25	0.07	0.013	28
Hedera helix	English ivy	herbaceous	0.063	0.64	0.063	0.012	24
Lonicera japonica	Japanese honeysuckle	herbaceous	0.32	0.45	0.32	0.023	88
Microstegium vimineum	Japanese stiltgrass	herbaceous	0.32	0.44	0.32	0.023	88
Rosa multiflora	multiflora rose	herbaceous	0.13	0.25	0.13	0.017	47

[1]Occupancy based solely on the raw data, not corrected for detectability
[2]Probability of finding a species in a particular quadrat if it is present in the plot
[3]Occupancy corrected based on the detectability of the species.
[4]Standard Error

In addition to distribution, the NCRN also measures the percent of each quadrat covered by each species. While invasive species are widespread in the region, no individual species has been found on more than one third of all plots (Table 2). Analyzing the percent cover data will present the same challenges as analyzing basal area and density of trees and shrubs. Currently, the NCRN plans to use a generalized linear model approach to analyze this data as outlined under measurable objective 2 above.

Measurable Objective 6 – Exotic Vines on Trees

For this measurable objective there are two analyses to consider, how common are the exotic vines, and which species of tree are susceptible to exotic vine species. In the future the NCRN will seek to compare mortality rates between trees with and without exotic vines, but there is currently insufficient data for a power analysis.

The occurrence of exotic vines on trees can be measured as presence or absence on plots like that of tree species discussed in Measurable Objective 1 above. In that case the results for the power analyses for trees are equally applicable to vines (Table 1).

The NCRN can also look for trends in the proportion of trees per plot that have vines. After sampling 300 plots, only 22% of them have any trees with vines. Therefore, like the basal area and tree density from measurable objective 1, this data follows a tweedie distribution and will have to be analyzed using generalized linear models.

Measurable Objective 7 – Pests and Pathogens

In principal, the pest and pathogen data can be analyzed in much the same way as the data from exotic vines on trees. However; in practice, the analysis may have very low power. Some pathogens, such as hemlock wooly adelgid are present in the NCRN but can only occur in the relatively small number of plots where hemlocks occur. After three years of sampling, hemlocks have only been found in four of the 300 plots. It is likely that the number of plots with any particular disease will be so small that the NCRN will have little power to detect trends. So far, the most commonly encountered insect pest is gypsy moth, which occurred on 39 of the 300 plots. At 400 plots the NCRN does not have a power of 0.8 to detect a change representing an increase of 50%, but we do have sufficient power to detect a 50% decrease (Table 2). Note that the sample design will have more power to detect a decrease in gypsy moth distribution than an increase. However the monitoring program can play a vital role in alerting park resource managers to emerging threats in their parks, even if the data is not used quantitatively.

Field Methods

Field Season Preparations and Equipment Setup

At the beginning of each calendar year NCRN permanent staff will review permits for monitoring all NCRN parks and submit permit renewal requests and investigator's annual reports to the parks as necessary. All field equipment will be inspected by NCRN staff and new equipment or supplies will be purchased as necessary.

A series of maps will be made or updated to help the field crew locate the monitoring plots in the field. The field crew will also be provided with a list of phone numbers and contact procedures for parks that have special requirements for entering certain areas (e.g. working along the Baltimore-Washington Parkway).

Initial ground-truthing and plot setup can take place year round. Prior to plot setup, rebar stakes and survey markers must be prepared for each plot.

Field Season Scheduling

Initial Ground-Truthing

Ground-truthing of the plots consists of an initial visit to determine if the plot is suitable for forest condition monitoring. SOP 1 details how this assessment is made. Ground-truthing can occur year-round. The only equipment needed for ground-truthing is a GPS and only a few minutes are spent at any one point. Typically 7 or more points can be checked in a single day.

Approximately half of all points which are checked in the network are unsuitable for forest monitoring. Nearly all of these are due to the point being located on land that is in easements rather than owned outright by the park service, or being found in a non-target habitat such as a field or road. A very small number are found in forests but are too hazardous or otherwise unsuitable.

As plot setup requires more staff time and more equipment, it is recommended that all plots be ground-truthed before setup to avoid wasted trips.

Plot Setup

Plot setup occurs after a location has been ground-truthed and the park it occurs in has granted permission for monitoring but before the first data collection begins. During plot setup permanent marking stakes are set in the ground and trees are tagged and marked at 1.37m for measuring the diameter at breast height. Methods for plot setup are discussed in SOP 2. Plot setup can occur any time of the year, but a plot must be set up before it can be monitored. On average, two plots can be set up in a single day by two people, including travel to and from the sites.

During 2006, the first year of monitoring, plot setup took place during spring and summer. This required two teams in the field, one with two people doing setup and the other of three people taking the measurements. After measurements were completed in the summer of 2006, one field crew continued to set up plots during the fall and early winter. The remaining plots were set up in spring and early summer of 2007. The 2007 field crew monitored the plots for that year, and then set up the next year's plots in the fall. This system will continue until all 400 plots have been installed. After the initial four years of setup, fewer new plots will be needed, largely to replace those which must be removed from the monitoring for some reason. This will take place during the spring or summer, when the need becomes apparent.

Plots should also be added when a location which was previously rejected becomes suitable. Examples of when this can occur include when land in the sampling frame is acquired by the park service or when a field is reforested. This may bring the sample size above 100 plots per year. This will be a rare occurrence this should not pose a problem for the field crews.

Monitoring

Monitoring can take place between May, when the canopy develops, and leaf off, which typically takes place in early to mid October. Ideally field crews will start as early in the season as possible to insure that all plots are monitored before the end of the field season. In the first three years of monitoring, measurements have taken approximately 17 weeks to complete. This includes sick and vacation days for the crew, rain days, holidays etc.

Measurements and Post-Collection Processing

The forest condition monitoring field crew will meet at the I&M office in Washington DC each day. The crew will collect equipment and travel to a network park for monitoring. The crew will plan the day-to-day schedule themselves and contact the park managers or other personnel as necessary. A small number of plots are located at the western end of the C&O Canal near Cumberland, MD. As these are far from the I&M office the crew will stay in that area overnight so that more time can be spent at those plots. The crew should decide on a date to do this and work with the network coordinator to make necessary travel arrangements. When returning from the field, the crew will download data and digital photos at the I&M office.

All measurements are described in SOPs 5 to 10. No laboratory processing is planned, except for plant species identification that cannot be done in the field. The botanist on the field crew will use appropriate methodology to collect unknown plants outside the sample plot, if possible, for later identification (SOP 11).

Official vouchers that have been identified will be stored at the NPS Museum Resource Center unless otherwise designated by a park. A temporary field herbarium may be created for training purposes during the field season. Plants used for a field herbarium do not constitute official vouchers and will be stored in the I&M office.

End of Season Procedures

After measurements have been taken on all plots, the field crew will meet with the data managers to determine if there are any plots with missing or incorrect measurements. The crew will then revisit those plots and verify the correct measurements. This can be combined with setup of nearby plots for the next year.

Data Handling Analysis and Reporting

Metadata Procedures

Any dataset compiled by the NCRN must be accompanied by Federal Geographic Data Committee (FGDC) compliant metadata. This includes both spatial and non-spatial datasets. Certain metadata fields will be incorporated into the project database but additional metadata documentation is often required. Specific metadata requirements can be found in the NCRN Metadata SOP.

Overview of Database Design

The project database is based on the back-end database design of the Natural Resources Database Template (NRDT). The NCRN deploys field crews with tablet PCs, which run the project database in the field. Crews enter vegetation data directly into the project database thereby eliminating the need for paper field forms. The database incorporates many functions and utilities to help reduce the possibility of data entry errors and promote data integrity. Entering the data in this manner eliminates the need to transfer data from paper data forms into a project database running on a desktop PC. Eliminating this step adds an additional level of quality control. Paper datasheets are available to the crew in the field, but only as a backup in case of a computer failure.

Data Entry, Verification and Editing

As mentioned above, ruggedized tablet PCs are used by field crews to enter vegetation data directly into the project database. This increases the integrity of the data by eliminating the step of transferring information from field forms to the database at a later time. Field crews are responsible for verifying the data entered into the database and the crew leader is responsible for ensuring that all datasets undergo complete QA/QC. Certain QA/QC measures are incorporated into the data entry forms of the database including pick lists and automatically populated fields. SOP 12 covers the QA/QC and other data management performed by the field crews.

Recommendations for Routine Data Summaries, Tables, Figures and Statistical Analysis to Detect Change and Trends

After each year of data collection the NCRN will prepare an annual report. The annual report will focus on the activities of the previous year and contain data summaries at the regional and park level (SOP 13). The primary purpose of the report is to inform park managers and other interested parties of new information that has been generated during the field season. The annual report with have summary information on density and basal area of all trees, shrubs and saplings, seedling density, volume of coarse woody debris, and presence of invasive species and forest pests. In order to prevent excessively large annual reports, not every field measurement will be reported. Once plots are being re-measured, the annual reports should compare the current year’s data to previous measurements on the same set of plots.

Every four years, once all plots have been sampled, the network will prepare a status and trends report based on the complete dataset. Once trend data is available, this report will be more focused on trend detection than the annual reports, and will be more statistical in nature.

The NCRN quantitative ecologist should work with the data manager to incorporate routine summaries and analysis directly into the project database. This will speed the process of producing annual reports and will keep the reports consistent even when there is staff turnover.

Recommended Reporting Schedule and Format

Annual reports will be prepared in the fall and winter following each field season. Status and trends reports will be prepared every four years after each complete sampling of the plots. These reports will be published in the National Park Service's Natural Resource Technical Report Series. Formatting will follow current guidelines for that series (NPS, 2006).

In addition to the regular reports, additional reports will be prepared when appropriate. These might include specific reports prepared at a park's request, input into a park planning document or journal publications.

Recommended Methods for Long-Term Trend Analysis

Methods for trend analysis will change as more data accumulates. In general trend analysis will focus on comparing measurements from each plot to measurements of the same plot taken in earlier years. During the first four years of monitoring, trend analysis will not be performed as each plot will only have been measured one time.

During the second round of sampling (years 5 through 8), it will be possible to compare between the first two rounds of sampling. At this time, tests for differences in means can be used to detect changes. This may include matched t-tests, generalized linear models or non-parametric tests, and some life history table analysis, depending on the data.

As more data accumulates, different analyses will become more appropriate. This could include regression analysis, longitudinal analysis, or life history table analysis depending on the specific question and the data available.

Data Archival Procedures

Data is transferred from the field team(s) to the I&M Data Manager on a daily basis. The data is maintained on the I&M file server in the proper project folder and considered "Active" until the completion of the field season. After each field season, project data from that season is aggregated and archived in the project folder under the "Archive" directory. Prior to archiving, the data must be verified and validated through proper QA/QC procedures. Once this has been done, the dataset is considered certified and can be archived. The archived datasets are stored under the Archived folder for that project which is formatted as "Read Only" for everyone except the I&M Data Manager.

In addition to archiving electronic data, any hard copy materials and vouchers are archived at the regional museum resource center (MARS) at the end of each field season. For additional information about archiving procedures see the NCRN Digital Data Storage SOP, Print Media Storage SOP and the Voucher SOP available in the NCRN Data Management Plan (National Park Service, 2005b).

Personnel Requirements and Training

Roles and Responsibilities

Network Coordinator

The network coordinator oversees all administration of the forest monitoring. This includes hiring personnel, making purchase and travel arrangements, managing the budget and any contracts or agreements relevant to the monitoring. The network coordinator is the official supervisor of the field crew. The network coordinator also participates in field crew training and performs field work on an ad hoc basis.

Quantitative Ecologist

The quantitative ecologist oversees technical aspects of the forest monitoring. This includes protocol development, site selection, site setup, data analysis and reporting. The quantitative ecologist acquires the permits and prepares Investigator's Annual Reports (IAR's). The quantitative ecologist provides the crew with maps and directions to all of the plots. The quantitative ecologist also participates in field crew training and performs field work on an ad hoc basis.

Data Manager

The data manager is responsible for providing database training to I&M permanent staff and field crews and ensuring that all those involved in the project are aware of their data management responsibilities. All data transfers and data archiving will be facilitated by the data manager. The I&M data manager will be responsible for providing any database assistance as well as GIS support when needed. The data manager will also archive documents and specimens with the regional museum. The data manger will help with field work on an ad hoc basis. Since 2006, the NCRN data manager has been aided by a term appointment GIS specialist.

Vegetation Monitoring Crew Leader

The vegetation monitoring crew leader will be responsible for managing vegetation field crews. The crew leader should be skilled in botany with a strong knowledge of flora of the mid-Atlantic region. The crew leader will determine the daily schedule for field work and coordinate with park staff. The crew leader will make sure all field crews are properly trained in data collection and use of the database. The field crew leader will regularly participate in field work.

Two Field Crew Members

The field crew members carry out the monitoring in the field and make sure all data is entered in the database.

Training Procedures

Field training for correctly executing the SOPs should be decided by the I&M Network Coordinator.

Operational Requirements

Annual Workload and Field Schedule

The process of hiring field crews should begin as soon after the beginning of the fiscal year as possible, due to the length of time it takes to hire seasonal staff. Investigators annual reports are due early each calendar year, and permit applications should be submitted in January or February of each year to make sure that any issues are resolved before the field season begins. Scheduling for field work is discussed above.

Work on the annual reports can begin after the field work has been completed. The annual reports should be finished in the spring after each field season.

Facility and Equipment Needs

The field crews will be based at the Center for Urban Ecology office in Washington DC. In addition to the equipment listed in SOP 2 and 3, the only equipment required will be access to computers and software for analysis, reporting and archiving. A small amount of additional supplies may be required to prepare voucher collections of plant species. The field crew will need to have access to a four wheel drive vehicle for the entire field season.

Startup Costs and Budget Considerations

We have estimated the costs for 2006, the first year of implementation of the protocol. This has been broken into two components – costs associated with existing full time network staff (Table 3), and those which are specific to this particular protocol (Table 4). Three existing staff members are expected to be involved in the protocol: the network coordinator, the quantitative ecologist, and the data manager. The term GIS specialist also provided considerable help. Full time network staff will also assist the field crews on an ad-hoc basis, particularly at the initiation of the field season when crews are undergoing training and to cover for occasional absences of field crew members.

Table 3 Startup costs: allocation of existing staff costs to protocol.

Position	Work Weeks	1st Year Cost (2006)
Network coordinator (GS-12)	14	$23,000
Quantitative ecologist (GS-12)	20	$34,000
Data manager (GS-11)	5	$7000
GIS specialist (GS-9)	8	$9000
Total		$73,000

Table 4. Startup costs: new staff and equipment to implement protocol.

Position	Work Weeks	1st Year Cost (2006)
Field crew leader (GS-7)	26	$19,802
Two field crew members (GS-5)	26	$31,972
Miscellaneous equipment and supplies		$21,000
Total		$72,774

This specific protocol requires the network to hire three seasonal employees. These include a field crew leader who will be responsible for carrying out the protocol in the parks. Additionally, money is allocated to purchase equipment related to plot setup and measurement. After the plots are established and basic equipment needs are met, it is anticipated maintenance cost for plots and equipment will be lower.

Revision History

Version 2.0 (May, 2009)

- Protocol reformatted for publication in NRR report series
- Updated methods section to reflect the decision to sample 400 plots
- Updated sections on reporting to match current practice
- Improved text throughout

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2008.

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SOP 1: Ground-Truthing Potential Monitoring Locations (March, 2009)

Version 1.0

Introduction
This SOP describes how to ground-truth potential monitoring locations for the NCRN forest condition protocol. This includes visits to the location, determining if it is suitable, and taking appropriate notes. Ground-truthing requires one person and can take place at any time of year.

Preparing for Field Work
Before heading out to the field, you must develop a list of locations to be ground-truthed. The NCRN data manager and quantitative ecologist maintain the list of potential locations and their GRTS number.

Start with the lowest GRTS numbers that have not already been used or rejected. Plot locations are used in order by GRTS number, but it is not necessary to ground-truth them in that order. Rather you should visit groups of close by points on the same day, even if they are not strictly in order. In practice, about half of all locations are rejected, so ground-truth at least twice as many locations as you think you will need.

The first step in the process occurs in the office. Using the GIS, determine the ownership for every plot location you are considering. If any location is not owned by the Park Service, it is automatically rejected and should not be visited. Keep in mind that the park service acquires and looses land from time to time, so be sure to use current information. Land owned by the NPS is often referred to as "fed-fee" land to distinguish it from land which the NPS does not own outright, but instead has easement rights.

Print out maps of all of the potential locations to ground-truth in each park.

Before heading out, be sure you are familiar with how to use the GPS and the TerraSync database on the data logger.

Equipment List
The following equipment is needed in the field

- Trimble GPS, including receiver, antenna, data logger, batteries and magnetic roof mount
- Maps to plot and 2 copies of research permits
- Insect repellent
- Laser rangefinder or clinometer to measure slope.
- Lunch, water etc.
- Digital camera
- Compass
- Paper and pen

Field Work

Assessing the Location

Drive to a convenient parking spot and leave a copy of the research permit in the windshield of the car. Carry a second copy of the research permit with you. Using the GPS, navigate to the potential plot location. Usually you can visit 7 or more points in a park in one day. Typically you can assess the location if you get to within 2m of the point. However, in cases where you are near to a road or forest edge, or where the slope is near the 30% cutoff, you should get to within 1m to assess the point. To assess the point consider the following:

- Is the entire potential plot in a forest or land that is reverting to forest from some other land use? In the NCRN forest (including wooded wetlands) and marsh are the only natural habitats you are likely to encounter. Therefore, assume that any canopy opening or abandoned farm field will revert to forest. Land that the parks are managing to prevent succession – e.g. mowed fields, is not considered potential forest. If any part of the plot is not forest or potential forest then the point is rejected.
- Is any part of the plot mowed or trimmed? In some parks there are wooded picnic areas and campgrounds where underbrush is routinely trimmed. We do not monitor forest conditions in these areas. Areas that are undergoing treatment for exotic plants, but are not otherwise mowed are suitable for forest monitoring.
- How steep is the slope? If the slope is steeper than 30° the location is not used due to safety concerns for the crew and potential damage to the understory. When assessing this, consider what the crew will actually need to walk across. Very small steps or steep spots that the crew can easily avoid should not automatically disqualify a plot if they will not interfere with monitoring.
- Is the plot entirely on fed-fee land? In some cases what is shown on the GIS does not match the situation on the ground. These cases need to be discussed with park staff.
- Does a larger stream or river run through the plot? Plots are monitored in locations with seasonal streams, or small streams with forest vegetation in them. Plots containing streams that are typically more than 50cm deep and have cleared their channel of vegetations are not used. In some locations, such as along the Potomac, the edge of the river is a wooded wetland and water can be deeper than 50cm at times. As long as the entire plot will be in the wooded part, this habitat can be used as a forest monitoring location.
- Is there a road in the plot? Locations with paved or dirt roads are not monitored, but locations with foot paths are monitored.
- Is there any unusual safety hazard for the crew? Dangerous locations are not monitored. An example of an unusual safety hazard would be an abandoned building which is near the plot and could collapse on the crew.
- Is there any archeological or cultural resource that would be disturbed by forest monitoring? The NCRN staff will discuss these locations with the park staff, but they will most likely be eliminated.

Data Entry

Once you have arrived, open up the data screen for that point in TerraSync on the data logger. The logger will display the park name, plot code and GRTS number; make sure you are entering data for the correct point. Enter data into each field as follows;

- Visited: Mark Y if you have visited the plot. Plots that are not on fed-fee land can be marked with an N.
- Forest: Mark Y if this location is suitable for a forest condition plot, N if it is not and "?" if you are unsure. Reasons to be unsure would include a slope that is difficult to measure alone, poor GPS precision in an area that is near to a non-forest habitat, or land use that is not immediately clear and input from park staff is needed.
- Habitat: choices include Grass (including crops), Marsh, Water, Road, Swamp (wooded wetland), Rec (recreational area such as a ball field or yard of a visitor center), Forest and Building.
- Anderson 2: choose the appropriate Anderson Level 2 habitat classification.
- Slope: choices are Flat, Hill and Too Steep (for location with a slope > 30°).
- Photo: Y or N, if you took photo points at the location (see below).
- Notes: Enter anything noteworthy about the location. If you put N in the forest field, and the habitat is forest or swamp, be sure to indicate why the point was rejected. If you put "?" in the forest field, be sure to indicate why you are not sure if the plot is suitable or not.

Photo Points

Take a set of photo points using the photographic methods outlined in SOP 5, even if the location is rejected. For these points there will not be a plot center stake, so take a photo of a piece of paper with the following metadata: date, GRTS code and plot name. Then take a series of six photos from the plot center facing out as indicated in Table 5.

Table 5. List of photo points for ground-truthing.

Photo	Angle	Orientation	Distance
1	none	none	Paper with metadata.
2	060°	horizontal	Center facing out
3	060°	vertical	Center facing out
4	180°	horizontal	Center facing out
5	180°	vertical	Center facing out
6	300°	horizontal	Center facing out
7	300°	vertical	Center facing out

Post-Fieldwork

After you have returned, download the data from the data logger to the appropriate place on the server as indicated by the NCRN data manager. Prior to plot setup, the potential plot locations must be approved by park natural resource managers. They should be included in the annual permit application submitted in the park, but if necessary new locations can be approved between permits.

Revision History

Version 1.0 (March, 2009)

- Original version of the protocol, in use since 2005, but formalized as an SOP in March, 2009.

SOP 2: Plot Location and Establishment (March, 2009)

Version 2.0

Introduction

This SOP describes how to establish permanent plots for the NCRN forest condition protocol. The plot setup will include placing permanent makers in the ground, tagging trees, marking dbh and determining the distance and azimuth of each tree relative to plot center. Shrubs and saplings are also tagged and marked.

Preparation

Before setup can begin, permanent markers must be prepared. Each potential plot location (intersection on the GRTS grid) has already been assigned a plot code based on the parks 4 letter acronym and a number. The number is based on the location of the potential plot in the park, with the northwestern most point numbered as “1” proceeding to the last numbered plot in the southeast corner. Most of these points will not be used for monitoring, but the plot numbers have already been assigned in order to provide a consistent numbering scheme across protocols, even if a future protocol should take a new random draws from the points. The NCRN data manager has the plot code for each location.

The center of each plot is marked by a piece of rebar ¾” × 18” topped with an aluminum survey cap. The survey cap has “U.S. Dept of Interior”, ”Vegetation Plot”, “Inventory & Monitoring” and “National Park Service” stamped on the edges. The center is left blank. Prior to fieldwork, use a metal die set to punch the plot code into the survey cap. Once the cap is marked, place it on the rebar and use liberal amounts of plastic steel putty to fix it in place. The plot center marker should then be left for several days to dry and cure.

Six smaller rebar stakes, measuring ½” × 12”, are used to mark the centers of the microplots and the ends of each transect. Prior to going in the field, use the rebar bender to bend about 3” of each of the smaller stakes at a 90° angle. The long end of the rebar will be driven into the ground. The smaller bent end will remain above and flush with the ground. The bent end will present a greater surface to the metal detector and make it easier to find in subsequent visits. The end where the rebar enters the ground is the microplot center.

Finally, the location of the plot must be loaded into a GPS system. For initial plot setup it is important that the center of the plot be located as closely as possible to the coordinates from the GIS. Therefore, take the GPS with the greatest accuracy, such as a Trimble Pro-XR with an integrated beacon that allows for sub-meter accuracy. The list of locations is kept by the NCRN data manager.

Equipment List

The following equipment is needed in the field:

- Trimble GPS, including receiver, antenna, data logger, batteries and magnetic roof mount
- Maps to plot and 2 copies of research permits
- Laser rangefinder with built in digital compass
- Tripod and tripod mount for rangefinder

- PVC pole with dbh marked
- Plot center marker
- Six smaller bent rebar stakes
- Rubber mallet
- 2.5 lb sledge hammer
- Claw hammer
- Board with reflective tape
- Notebook with water proof paper
- Pens and pencils
- Compass
- Tree tags (about 150 per plot)
- Aluminum nails
- 6 Chaining pins
- Leather sheath for chaining pins
- Flagging tape
- Tree marking spray paint
- Pistol grip for spray paint
- Plastic cable ties
- Calipers
- Sonar rangefinder
- 30 m tape measure
- Dbh tape
- Leather holster for dbh tape
- Utility apron
- Orange safety vest when working along busy roads
- Spare batteries
- Insect repellent
- Calculator

Plot Location and Marking

Drive to a convenient parking spot and leave a copy of the research permit in the windshield of the car. Carry a second copy of the research permit with you. Navigate to the plot using the GPS. Once at the plot find the plot center to within 1 m. It helps to make a small mark in the dirt with your boot so that you can locate the point again after you have removed your pack.

Use the rubber mallet to pound the plot center marker into the ground until top of the survey cap is flush with the ground. That is, the plot center marker should not stick up. Do not hit the plot center marker directly with the sledge as this will damage the aluminum survey cap and make the plot code hard to read. If you need more force than the mallet can provide, place the head of the mallet on the survey cap, hold the mallet handle with one hand, and hold the sledge in the other. Hit the mallet head with the sledge, thus protecting the survey cap.

If a rock blocks the point at the center of the plot, move the center marker the shortest distance possible and sink it there. If you need to move the center more than 1m, than you should make a small mark on the rock with the tree marking paint and place the plot marker in nearest possible place. Note the center is marked with paint in the notebook and give the direction and distance from the plot maker to plot center. However, do not mark the rock with paint if you are in a location that has high visitor use or if the obstruction may have archeological or cultural significance. In that case, don't set up the plot, instead the NCRN permanent staff will contact resource managers to figure out what is best to do at that particular site.

Monitoring Plot Layout

The layout of the monitoring plots is diagramed in Figure 3, below. Important features of the plot include:

Plot of 15-m radius for live trees ≥ 10-cm dbh (diameter at breast height).

Microplots of 3-meter radius for trees 1 to 10 cm dbh and shrubs ≥ 1cm drc (diameter root collar). Three microplots are at 60°, 180°, and 300° and 10 m from plot center.

Quadrats (2×0.5 m) for select herbs and shrub/tree seedlings (<1 cm dbh or drc). Located along **3 transects** at 360°, 120°, and 240° from plot center, where 3 quadrats are placed to right of each transect with lower corner at 3, 8, 13, meters (3 quads per transect) and in the center of each microplot (Total of 12 quads per plot). The quadrats are rectangular, rather than square, to make them easier to monitor without steeping inside and trampling them.

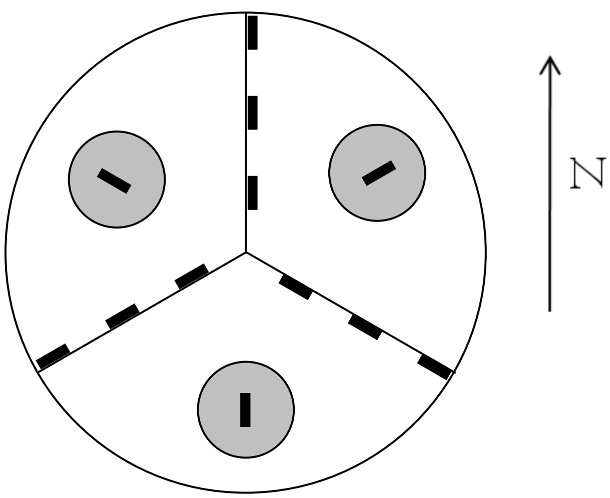

Figure 3. Layout of forest monitoring plots.

Flow of Work

If two people are setting up the plot, one person should remain at plot center. That person will operate the laser rangefinder and take all of the notes. The other person will install the transect and microplot center markers and paint and tag the trees. Once all trees are tagged, both field workers will mark, tag and record saplings and shrubs in the microplots.

If three people are setting up a plot, and the plot is relatively open, the third person can start tagging and marking the trees while the other two place the plot markers and measure the distances and the azimuths to the trees. Alternatively, if the forest is unusually dense and microplot setup will take a long time, the third person can setup the microplots while the other two work on plot markers and trees.

Marking Transects and Microplots

Once the plot center marker has been installed, calibrate and setup the laser rangefinder. The rangefinder should be directly above plot center. Using the digital compass setting, one crew member should point the rangefinder to magnetic north. A second crewmember should take the board with reflective tape, the bent rebar stakes the chaining pins and the sledge hammer to install the stake. The first stake is installed at 360°, 15m distance and is the end of one of the transects. The crew member at plot center should direct the person at the edge of the plot until they are straight north. Aiming at the board with reflective tape as a target, use the rangefinder to direct the crew member with the stakes to 15 m out. When measuring the distance be sure to use the horizontal distance, not the distance along the slope. The laser rangefinder can provide this distance. You should get to within 20 cm and 1° of azimuth from the designated location before installing the stake. Pound the long end of the stake in until the bent portion is flush with the ground. Insert one of the chaining pins with flagging next to the stake to mark its location. If a rock blocks the marker, go to the nearest possible location to insert the marker and place blue paint on a rock to mark the true location. If the plot is in a highly visible location or has cultural or archeological significance, don't set up the plot. The order of stakes to be set up is shown in Table 6.

Table 6. Order of installation of plot markers.

Azimuth	Distance from Center	Purpose
360°	15m	Transect
60°	10m	Microplot
120°	15m	Transect
180°	10m	Microplot
240°	15m	Transect
300°	10m	Microplot

Each stake should be marked with a chaining pin with flagging tape. It is helpful to use different colors of flagging tape to distinguish between the transect stakes and the microplot stakes.

Tagging and Marking Trees

What Is a tree?

For the purposes of this protocol a tree is an individual woody plant that is not on the list of shrub species (see SOP 8 for this list), that is located within the 15m radius plot, is living and that has a diameter or equivalent diameter of 10cm at dbh (diameter at breast height=1.37m).

When determining if a tree is located within a plot, measure from the center of the tree at breast height to the center of the plot. A tree whose center is ≤15m form the plot is considered in. To determine this, measure the distance from the center the plot to the edge of the tree at breast height. Then measure dbh. Add ½ of dbh to the distance from plot center to edge of the tree to get the distance of the center of the tree to plot center. If the tree has multiple stems at breast height, measure from the center of the group of stems.

A tree is considered to be living if it has living tissue (e.g. leaves) above breast height. If the tree has multiple stems at breast height, measure form the center of the group of stems. If a tree splits below the ground, so you cannot see the split, each stem is treated a separate tree.

The equivalent diameter criterion applies only to trees that split into two or more stems below dbh but above the ground. In general, we wish to include split trees that have the same or greater total basal area as a tree with a single trunk with a dbh of 10 cm. This is a departure from FIA methodology, which only includes trees where at least one stem has a dbh ≥12.7cm.

If any of the stems have a dbh ≥ 10cm, then the individual is included as a tree. If all of the stems are individually less than 10cm dbh, then the equivalent must be calculated. To calculate equivalent diameter, use the following equation:

$$Equivalent\ Diameter = 2\left(\sqrt{\left(\frac{Diameter\ of\ stem\ 1}{2}\right)^2 + \left(\frac{Diameter\ of\ stem\ 2}{2}\right)^2 + \left(\frac{Diameter\ of\ stem\ 3}{2}\right)^2 \ldots\ldots etc}\right)$$

For simplicity Table 7 can be used as a guide to situations commonly encountered when a tree splits into two stems. Note that for trees with two stems, if both stems are ≤ 7cm, then the tree is always too small. If for some reason you are unsure if you should include a tree or not, include the tree as it will removed later during QA/QC if it is too small.

Table 7. Stem sizes for an equivalent diameter ≥10cm.

Largest Stem dbh	Requirement for dbh of Smaller Stem
9.9 cm	≥1.41 cm
9.5 cm	≥3.12 cm
9.0 cm	≥4.36 cm
8.0 cm	≥6.00 cm
7.07 cm	≥7.07 cm

Measuring Diameter

The diameter measurement is not recorded when the plot is established. However, in order to determine which individuals are trees and to mark the trees, the setup crew needs to understand how diameter is measured.

Dbh is measured to 0.1 cm at 1.37 m along the length of the tree from the ground. Trees on a hill should be measured on the uphill side of the tree. Leaning trees should be measured on the short side (Figure 4).

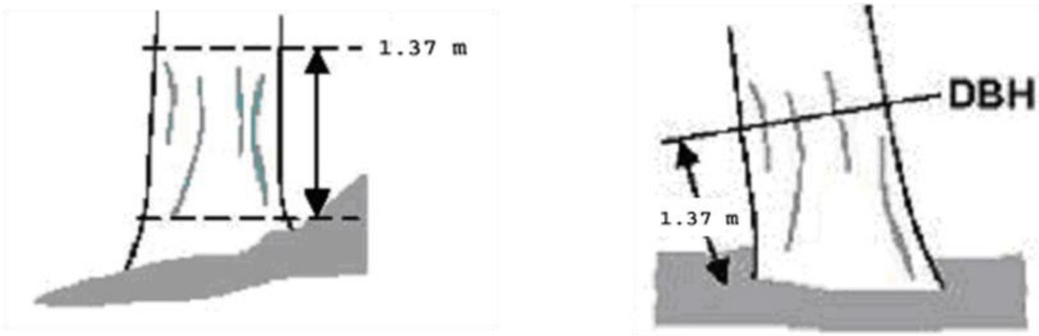

Figure 4. Location of DBH on hills and leaning trees.

If there is an abnormality at dbh, take the measurement just below the abnormality if possible, marking the tree at the measurement point. If the abnormality extends far below dbh, then take the measurement just above dbh.

If the tree forks, measure each stem of the tree. Always record the dbh of all separate stems before performing the calculation needed to derive the equivalent diameter. If the forking influences the diameter of the stems at the dbh, then treat the forking as an abnormality as explained above. If a tree appears to fork beneath the ground, but the trunks are not visibly connected at the surface, mark and tag them as two separate trees.

If a tree bends or sags, measure the 1.37 along the length of the tree. Do not try to find a spot that is 1.37m above the ground which may be much further along the stem.

If a vine is growing on the tree attempt to measure the dbh by sliding the measuring tape between the vine and the tree. In some cases this will not be possible, then measure the dbh with the vine. Be careful when working with trees that have poison ivy (*Toxicodendron radicans*) growing on them. Poison ivy is very common through the parks in the region.

Tagging Trees

The NCRN uses aluminum tree tags engraved with “U.S. National Park Service, Forest Monitoring, Do Not Remove” and then a unique identifying number. Each tree, sapling and shrub is given a tag, seedlings are not. When a tree splits into two or more stems, the entire tree gets a single tag, do not tag each individual stem. Do not worry about putting all of the tags in any particular numerical pattern or order. As existing trees die and new trees grow, any order will be lost.

In general, tags should be placed so that they are facing the plot center as this will help field workers to locate the center marker. However, when the plot is near a road, trail or other high traffic area, the plot should be as inconspicuous as possible. Place the tags so that they are facing away from high public use areas.

There are two methods used for tagging trees. In most cases you should attach the tag to the tree using an 2 ¼″ aluminum nail. The tag should be placed at shin height, as this will be less conspicuous. Hammer the nail about 1/3rd of the way in, angling downward. This will allow the tag to hang away from the tree and not be swallowed up as the tree increases in diameter.

The other option for tagging trees is to attach the tag using plastic cable ties. These are best for small diameter trees and saplings. Park managers in Catoctin also prefer that trees in that park are tagged using cable ties rather than nails. In practice you will need to string two or more ties together in order to reach around a tree. Make sure there is plenty of slack in the tie so that the tree has room to grow. The tag and ties should rest on the ground.

Marking Trees

In order to accurately re-measure dbh at the same point on successive visits, each tree is marked at dbh. Use a PVC poll with a mark at 1.37m to determine where the measurement should be taken on the tree. Then paint a horizontal line on the tree using the tree marking paint. Try to make the line as thin as possible. In general, the line should be made facing plot center. However, as with the tags, the line should not be visible areas with high visitor traffic, such as trails and roads.

Measuring Distance and Azimuth

Measure the distance to 0.1m and the azimuth to 1° of each tree with respect to the center of the plot. When measuring this distance for a tree with one main stem, measure from the edge of the tree closest to plot center. Once the diameter is measured during monitoring the distance from the center of the tree to plot center can be calculated. If the tree has multiple stems at breast height, measure from the center of the group of stems.

In general this can be accomplished using the digital compass and rangefinder along with the reflective tape target. Occasionally, dense underbrush can make it difficult to measure the distance with the rangefinder. In these instances the sonar measuring device will work. In the unlikely event that neither of these works, use the 30m tape measure. In all cases measure the horizontal distance, not the distance along the slope.

Setup of Microplots

Each plot has three circular microplots, each with a 3m radius. The centers of the microplots are 10m from plot center, at azimuths of 60°, 180° and 300°. Use the sonar measurer or the tape measure to determine which shrubs and saplings are in the plot and tag them. When determining which saplings and shrubs are in the plot, be sure to use the horizontal, not the slope distance.

Saplings are non-shrub woody plants with a dbh ≥1cm and <10cm. Diameter at breast height for saplings is measured in an identical fashion as it is for trees. The one exception is that the equivalent diameter method is not used for saplings. Instead, for a sapling to be tagged at least one stem must measure ≥ 1cm at dbh. Sapling are painted at dbh in the same way that trees are.

Shrubs are woody plant species on the list of shrubs (SOP 8). Shrubs are tagged if their drc (diameter at root crown) is ≥ 1cm. Diameter at root crown is used rather than dbh, as many shrubs have a great number of stems at breast height and cannot be practically measured and marked. Shrubs are not painted at plot setup.

All tags and dbh marking should be placed so that they face the center of the microplot, not the plot. As with all other tags and marks, do not place them so they are visible to high visitor use areas.

Note Taking

One crew members should act as the note taker during setup. Be sure to note the following:

- The plot code assigned to the plot
- Date
- Crew members who set up the plot
- The tag number, distance and azimuth of every tree
- The microplot and tag number of each sapling and shrub
- Record if any microplot has no trees or shrubs at setup
- A brief description of where to park and how to get to the plot.
- Any problems or other comments

Cleanup

After setting up the plot be sure to remove the chaining pins from the transects and microplots. Do not use flagging to mark the route to the plots or the plots themselves.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Expanded explanation of equivalent diameter.
- Improved text throughout

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2008.

SOP 3: Office Preparations Pre- and Post-Monitoring and Field Equipment (March, 2009)

Version 1.0

Introduction

This SOP describes the steps that are taken each day before and after monitoring the plots and contains a list of equipment that is needed for fieldwork.

Preparations before Monitoring

Before heading to the field, verify that you have the maps and field work permits for the correct park with you. You may need to make special arrangements to work in some areas of the parks (e.g. the Baltimore- Washington Parkway, lands adjoining Quantico Marine Base), plan ahead accordingly. Check the field computers and the GPS to make sure that they have the plot data and the locations for the planned plots. If any of the data is missing, the data management staff can provide it. Make sure that someone at the office knows which park you are working in.

Field Equipment

The following equipment should be taken with you for collecting the monitoring data:

- Plot and the park maps
- Street atlas or vehicle based GPS unit
- Permits
- Hand held GPS
- Metal detector
- 2 Tablet computers
- Packing tape (for protection against tics)
- Insect repellent
- Copy of protocol
- Blank paper data sheets
- 2 Metal clipboards
- All weather paper
- 3 Back packs
- PVC quadrat frame
- 4 30m measuring tapes
- 2 compasses
- Spare tree tags
- Black zip ties
- Aluminum tree nails
- Hammer
- Forestry spray paint
- Pistol grip for spray paint
- DBH pole
- Binoculars
- 2 DBH tapes
- Pencils and pencil sharpener
- Spare batteries

- 4 Chaining pins
- 3 Pink marker flags
- Leather sheath for pins and flags
- Hand lens
- Digital camera with spare battery and memory card
- Sonar rangefinder
- 2 Meter folding rulers
- 12″ Ruler
- Throw rope (for obtaining plant specimens which are out of reach)
- Plant presses
- Whistle
- Field Guides
- Lunch, water, personal items

Post-Monitoring Office Work

After you return to the office, you should ensure that the day's data is properly archived. The data should be backed up to a USB key and passed on to the data manager. The data manager will provide training on this procedure (see SOP 12). The data manger will integrate this data with the main forest monitoring database on the I&M server.

The data manger will also provide hardcopies of the monitoring data for each plot after it has been monitored. Every crew member should review the data to make sure that it is accurate or complete. Indicate any problems on the data sheet and return it to the data manager. If data is missing the plot can be revisited to fill in any gaps.

Make sure that the tablet batteries are left to recharge overnight. Once a week, connect the tablets to their docking stations, and the internet and leave them on overnight. This will allow them to receive security updates and software upgrades.

Each day, obtain a blank data card for the camera and present the used card to NCRN data management staff (SOP5).

Be sure to report any equipment problems to the data manager or I&M coordinator.

Revision History

Version1.0 (March, 2009)

Original version of the protocol, in use since 2005, but formalized as an SOP in March, 2009.

SOP 4: Arriving at the Plot and Flow of Work (March, 2009)

Version 1.0

Introduction
This protocol describes how to find the plots and the general flow of work during monitoring.

Locating the Plot
You will be provided with a map and general directions to each plot. Drive to a convenient parking spot and leave a copy of the research permit in the windshield of the car. Carry a second copy of the research permit with you. Start the GPS and navigate to the plot. As you get near the plot you will usually spot trees which have been marked with forestry paint and tree tags.

To minimize the effects of trampling, leave the backpacks with equipment outside of the plot. Use the metal detector to find the plot center marker. It is helpful to remember that in most cases the tags and marking paint should point in towards the center stake. Once you locate the center stake, mark it with a chaining pin.

Flow of Work
Once the plot has been located, use a compass and the metal detector to locate the six bent pieces of rebar marking the ends of the transects and the center of the microplots. Mark the microplots with one of the marking flags. Mark the ends of the transects with chaining pins. Lay out the 30m tapes along the transects, using the chaining pins as anchor points.

Once the plot is completely marked, one crew member should take the photos (SOP 5) while the others boot up the tablets and start the databases. Generally monitoring works best if two crew members cooperate on taking the forest floor (SOP 6), tree (SOP 7) and microplot (SOP 8) measurements. The third crewmember should take the quadrat (SOP 9) and coarse woody debris (SOP 10) measures. While taking measurements be careful to minimize trampling of the vegetation, particularly in the quadrats.

Once the measurements have been taken, remove all pins, tapes and flags and pack up the equipment. Check the area to make sure nothing has been left behind.

Revision History

Version1.0 (March, 2009)
Original version of the protocol, in use since 2005, but formalized as an SOP in March, 2009.

SOP 5: Photo Points (March, 2009)

Version 2.0

Introduction

This SOP describes how to take a standardized series of photographs, called photo points, at each plot. The purpose of the photographs is to document the overall look of the plot. This will allow us to visually demonstrate the changes to the plots over time.

Photo Points

Photo points should be the first measurements completed when sampling a plot. Thirteen photos (Table 8) will be taken in JPG format and in the following standardized sequence with the camera focal length set to its widest angle. First, a close-up of the plot marker, then six (horizontal and vertical at each azimuth) from plot center facing the 10-meter mark at 060, 180, and 300 degrees, and six at 15 m taken towards plot center at 360, 120, and 240 degrees. The horizontal images should record a wide view of the forest floor and understory, the vertical should record the forest floor and what tree height can be included in the frame without tilting the camera up towards the canopy. The photographer should attempt to exclude the field crew from the monitoring photos. The chaining pins, flags and 30m tape should be visible in the photos when the vegetation allows it.

Table 8. List and sequence of photo points for monitoring.

Photo	Angle	Orientation	Distance
1	none	down	Plot marker close-up
2	060°	horizontal	Center facing out
3	060°	vertical	Center facing out
4	180°	horizontal	Center facing out
5	180°	vertical	Center facing out
6	300°	horizontal	Center facing out
7	300°	vertical	Center facing out
8	360°	horizontal	15m facing in
9	360°	vertical	15m facing in
10	120°	horizontal	15m facing in
11	120°	vertical	15m facing in
12	240°	horizontal	15m facing in
13	240°	vertical	15m facing in

If anything else unusual or noteworthy is the plot, take one or more photos to document it. These should be taken after the 13 standard photos.

Downloading Photos

Each day the memory card from the camera should be exchanged for a blank memory card. The used memory card should be presented to NCRN data management staff, the Visual Information Specialist, or a designated field crew member for transfer to the NCRN file server. As these photos will require additional processing and quality assurance they should not yet be stored with the verified monitoring photographs, but rather in a folder named ~Inbox, in a subfolder named with the date the photos were taken. For example:

T:\I&M\MONITORING\Forest_Vegetation\Photos\~Inbox\2008-08-11

Note that this dated subfolder may include photographs from multiple plots which will need to be segregated by examining the photo sequence and center stake photos during the renaming process. While it is always advantageous to do as much of the photo data management when memories of the event are still fresh, it is critical that the newly transferred photo sets are at least examined for completeness and to identify any camera malfunctions during this daily data transfer. On a weekly basis, all photos in the inbox should be renamed and moved to a permanent storage folder as described below.

Renaming Photos

Once photos have been copied from the camera to the NCRN file server they should be renamed using the following standard: PlotID_YYMMDD_Angle/Orientation or Description, with the three elements of the name separated by underscores. The photograph of the center stake should use a suffix of “plotcenter” instead of an angle/orientation, and any anecdotal photos should include a suffix that describes the item of interest in the photo with words separated by underscores so that filenames contain no spaces.

Example: CHOH-0026_061002_Gypsy_Moth
Example: MANA-0106_070612_plotcenter.jpg
Example: CATO-0275_070829_060h.jpg

PlotID Date Angle/Orientation or Description

Note that the leading zeros should always be included for the plot number, the date and the 060°Angle/Orientation.

For folders which contain photos from multiple events, the Plot ID will be identified by sorting the photos by the time-date stamp and looking for the center stake photo.

Storing Photos

The verified and renamed photos should be moved from the Inbox location to a permanent storage folder named for the plot where they were taken - for example *Forest_Vegetation\Photos\HAFE-0154* - and should be subject to NCRN standard archiving procedures. When this plot is revisited a second set of photos will be added to this folder, with the date portion of the file name distinguishing the two sets.

Keyword Metadata Documentation

At the close of each field season the verified, permanently stored photos should be tagged with embedded keywords in accordance with the NCRN photo documentation standards including, at a minimum, the embedding of keywords for Park Code, and “Forest Vegetation Monitoring”.

This documentation must be accomplished with metadata editing software that embeds the keywords permanently into the image/jpg file.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Improved text throughout

Version 1.0 (January 2006)

Version of protocol used from 2006 to 2008.

SOP 6: Introduction Tab and Forest Floor Measurements (March, 2009)

Version 2.0

Introduction

This SOP describes how to record information on the introduction and forest floor tabs of the database. The introduction tab includes basic metadata. The forest floor measurements are used to get a general idea of the ground cover of the plots.

Introduction Tab

Name

In the “Name” field, chose the names of the crew members taking the measurements from the dropdown list. The names of the crew will be added to the list by the data manager before the field season begins.

Permanent Notes

In the permanent notes box make any notes which relate to the plot itself and not just to this particular sampling event. This can include any safety hazards or hints on locating hard to find marking stakes, etc.

Event Notes

In the event notes box make any notes which are relevant to just this sampling event. This might include any unusual observations that are not captured elsewhere in the database.

Event Metadata

In the event metadata area, first indicate who entered the event metadata and the date. Once the photo points pictures have been taken, check the box labeled “Pictures Taken?”. If the plot needs further review, such as an unidentified species or if you are not able to collect all of the data on a single day, then check the plot review box and indicate in the review notes what needs to be done.

Forest Floor Measurements

The three forest floor measurements taken for this SOP are found on the “Forest Floor” tab of the database. They are meant to be estimates, do not attempt to measure them exactly. Each measurement is taken for the entire plot. The measurements are:

Rock cover – This is the % of the plot that is covered by large rocks. In most cases this will be low, but in some of the parks large rocks are a dominant feature of the landscape.

Bare Soil – this is the % of the plot that is covered by bare soil or by dead leaves (not living vegetation).

Trampled – this is the % of the plot that is trampled by a hiking trail or similar feature.

Each of these measurements is recorded by indicating which of the following broad classes it fits in: <1%, 1-5%, 6-25%, 26-50%, 51-75%, 76-100%. There is no 0% category as it would take considerable effort to determine that absolutely no rock, bare soil or trampled areas are present. In cases where there is apparently none present choose <1%,

Revision History

Version1.0 (March, 2009)

Original version of the protocol, in use since 2005, but formalized as an SOP in March, 2008

SOP 7: Tree Measurements (March, 2009)

Version 2.0

Introduction

This SOP describes procedures for taking data on trees that have a dbh ≥10 cm and are found in the monitoring plots.

What Is a Tree?

For the purposes of this protocol a tree is an individual living woody plant that is not on the list of shrub species (see SOP 8 for this list) and that has a diameter or equivalent diameter of 10cm at dbh (diameter at breast height=1.37m). A tree is considered to be living if it has living tissue (e.g. leaves) above breast height. If a tree splits below the ground, so you cannot see the split, each stem is treated a separate tree.

The equivalent diameter criterion applies only to trees that split into two or more stems below dbh. In general, we wish to include split trees that have the same or greater total basal area as a tree with a single trunk with a dbh of 10 cm.

If any of the stems have a dbh ≥ 10cm, then the individual is included as a tree, and all of its stems are measured at dbh. If all of the stems are less than 10cm dbh, then the equivalent must be calculated. To calculate equivalent diameter, use the following equation:

$$Equivalent\ Diameter = 2\left(\sqrt{\left(\frac{Diameter\ of\ stem\ 1}{2}\right)^2 + \left(\frac{Diameter\ of\ stem\ 2}{2}\right)^2 + \left(\frac{Diameter\ of\ stem\ 3}{2}\right)^2 \ldots\ldots etc}\right)$$

For simplicity Table 9 can be used as a guide to situations commonly encountered when a tree splits into two stems. Note that if a tree has two stems and both stems are ≤ 7cm, then the tree is always too small. If for some reason you are unsure if you should include a tree or not, include the tree as it will removed later during QA/QC.

Table 9. Stem sizes for an equivalent diameter ≥10 cm.

Largest Stem dbh	Requirement for dbh of Smaller Stem
9.9 cm	≥1.41 cm
9.5 cm	≥3.12 cm
9.0 cm	≥4.36 cm
8.0 cm	≥6.00 cm
7.07 cm	≥7.07 cm

Taking Measurements

Tag Number

First locate the tag that is attached to the tree. Select the corresponding tree in the database, or note the tree number on the datasheet.

Occasionally you will encounter a tree that does not already have a tag. This may be because the tag has been lost, the tree appeared dead when the plot was initially set up, the tree has grown since plot setup or the tree may have simply been missed. Record the distance and azimuth from plot center and place a new tag on the tree. If it appears that the tree was previously marked but has lost its tag, note the new tag number under the old tag number if you can determine it.

Tree Identification

We are recording the species of each tree so that we can relate species to habitat types and so we can determine if there are long term trends in the populations of individual tree species.

Record the scientific name of the tree. If the tree has already been identified, confirm the identification. If you find that it was identified incorrectly, note down the old ID, the new ID, your name, the date, and any notes that may be useful. Take a picture of the features you used to change the ID (bark, leaves etc). If you cannot identify the tree, take a sample to identify as indicated in SOP 11.

Measuring Diameter

Diameter at breast height is used to calculate the basal area of each tree. Basal area is an approximation of the area of the cross section of each tree at breast height. Basal area is used as a measure of the amount of living woody biomass in the forests and as a measure of importance of the various tree species. Measuring dbh will allow us to track trends in the basal area of the forests as a whole and of individual tree species.

Diameter at breast height is measured to 0.1 cm at 1.37 m from the ground. In most cases the tree will already be marked at dbh and the measurement should be taken at the marking. If the marking is off, take dbh at the mark. The only exception is if this is the first measurement of the tree and the mark is grossly in error. In that case remark the tree correctly and make note explaining the correction.

Trees on a hill should be measured on the uphill side of the tree. Leaning trees should be measured on the short side (Figure 5).

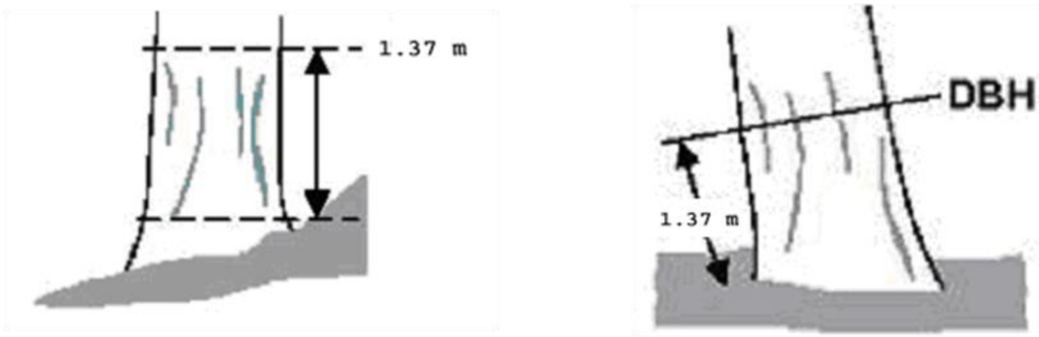

Figure 5. Location of DBH on hills and leaning trees.

If there is an abnormality at dbh, take the measurement just below the abnormality if possible, marking the tree at the measurement point. It is best to mark the tree first and take the measurement second. If the abnormality extends far below dbh, then take the measurement just above dbh, again marking the tree at the measurement site before taking the measurement.

If the tree forks, measure each stem of the tree. Always record the dbh of all separate stems before performing the calculation needed to derive the equivalent diameter. If the forking influences the diameter of the stems at the dbh, then treat the forking as an abnormality as explained above. If a tree appears to fork beneath the ground, but the trunks are not visibly connected at the surface, measure them as two separate trees.

If a tree bends or sags, measure the 1.37 along the length of the tree. Do not try to find a spot that is 1.37m above the ground which may be much further along the stem.

If a vine is growing on the tree attempt to measure the dbh by sliding the measuring tape between the vine and the tree. In the case this is not be possible, measure the dbh with the vine. Be careful when working with trees that have poison ivy (*Toxicodendron radicans*) growing on them. Poison ivy is very common through the parks in the region.

Vines on the Tree

Vines, including exotic vines, are found on trees throughout the NCRN. We are recording the scientific name of each vine found on each tree so that we can determine how common each species is and track change in abundance and distribution over time. If an individual vine is growing on more than one tree it is recorded for each tree. We are not taking additional measurements of individual vines, such as counting the number of individual vines in the plot or taking a dbh-like measurement as presence or absence on trees in sufficient for our purposes.

Record the scientific name of any vines growing on the tree. If you cannot identify the vine, take a sample to identify as indicated in SOP 11. If more than one vine species grows on a tree, record all species found. If no vines are growing on the tree, note that you completed this so that it is clear there are no vines and you did not just forget to take the data.

Once you have completed this section, check the associated “Completed” box. If you have determined that there are no vines in the tree, check the box anyway. This will allow us to verify that vines are truly absent and the crew did not forget to check for them.

Tree Conditions

A “tree condition” is any of a number of factors that might be expected to increase the mortality rates of trees. These conditions are recorded simply as being present or absent as it is too difficult to accurately quantify them. More than one condition can be recorded for each tree. The conditions are:

- Advanced Decay: Large portions of the tree are undergoing decay (e.g. heart-rot), but the tree is still alive.
- Primary Branch Broken: Main trunk of the tree is broken off. In the case of trees which split, if any main trunk is broken use this condition and make a note of the circumstances. This does not need to be selected if “Alive Broken” was chosen as the tree status (see below). In practice this will generally be selected some, but not all, of the main branches on a tree with a large split are broken, or when the very top, but not the entire crown of a tree is broken.
- Large Dead Branches: large branches on the tree are dead. If “Primary Branch Broken” is selected as a tree condition or “Alive Broken” is selected as tree status, this should not be selected unless you wish to indicate additional damage not already covered by those choices.
- Lightning Damage: obvious signs of lightning damage, such as large vertical burn marks on tree. You should indicate lightning damage only if you are sure this kind of damage has occurred.
- Wind damage: allows us to determine the extent of damage to trees due to storm events in the NCRN. In some locations, particularly in Catoctin Mountain Park, wind damage from storms can knock down stands of dozens of trees. Only select this if you are certain that wind is the cause of the damage you are seeing.
- Open wound: large open wound, such as from where a branch fell off.
- Vines in the crown: record if any vines on the tree grow into the crown. This is not recorded separately for each vine species as it can be difficult to identify vines that are high above the ground.
- Other Visible Damage: Any other damage that you feel could increase the mortality risk of the tree that is not covered here (note that wind and lightning damage is covered separately below). Record in the notes what the damage is.

Tree pests and diseases are also recorded in this section (see below). Once you have completed this section, check the associated “Completed” box. If you have determined that there are no tree conditions, check the box anyway. This will allow us to verify that tree conditions are truly absent and the crew did not forget to check for them.

Tree Pests and Diseases

Tree pests and diseases are one of the vital signs of the NCRN. These organisms can cause extensive mortality of native trees. The presence of these organisms is being recorded in order to understand their importance in NCRN forests.

In the database under the “Tree conditions” drop down box, record the presence of each pest or disease found from the list below (Table 10). The list is not meant to be exhaustive. Rather it is a list of tree pests and diseases which are known to be devastating to natural populations and that can be found in the area covered by the NCRN. Some diseases, such as Dutch elm disease, can kill individual trees, but are not a threat to wild populations, so they are not included. This list will be reviewed annually and updated as necessary. Spruce bud worm was initially included on this list, but was dropped after the 2008 sampling season as no spruce trees have been found. Information on identifying each pest or disease will be provided to the field crew at the beginning of the field season.

Table 10. Pests and diseases to monitor.

Pest or Disease	Scientific Name	Year Monitoring Began
Beech bark disease	*Nectria* spp.	2006
Butternut canker	*Sirococcus clavigignenti-juglandacearum*	2006
Dogwood anthracnose	*Discula* sp.	2008
Emerald ash borer	*Agrilus planipennis*	2009
Gypsy moth	*Lymantria dispar*	2006
Hemlock scale	*Fiorinia externa*	2008
Hemlock wooly adelgid	*Adelges tsugae*	2006
Other significant insect damage		2006

Foliar Conditions

A “foliar condition” is any of a number of factors that might be expected to increase the mortality rates of trees and specifically affects the leaves. These are being noted in an attempt to see if there is in fact a relationship between these factors and tree mortality.

Unlike the tree conditions above, foliar conditions are recorded and an estimate is made of the percentage of the leaves which are affected. More than one foliar condition can be recorded for each tree. The conditions are:

- Chlorosis: this is a loss of chlorophyll in the leaves which will be evidenced by an unseasonal loss of their green color.
- Holes: Small holes found in leaves, usually from insect damage
- Necrosis: leaves are dying
- Small leaves: some leaves are unusually small, usually due to damage during leaf development
- Wilting: leaves are wilted, usually due to water stress or damage to branches
- Other: Any other damage or conditions to the leaves that you feel could increase the mortality risk of the tree that is not covered here. Record in the notes what the damage is.

Once you have completed this section, check the associated “Completed” box. If you have determined that there are no foliar conditions, check the box anyway. This will allow us to verify that tree conditions are truly absent and the crew did not forget to check for them.

Tree Status

Tree status indicates if the tree is alive, dead, or no longer part of the study and if it is still standing. This information will be used to help understand causes of mortality and to track the reasons why trees are removed from the study. The tree status options are:

- Alive Standing: Tree is alive and is standing upright.
- Alive Leaning: Tree is leaning at more than 30° from vertical.
- Alive Broken: A large portion of the main stem of the tree is broken off. This should be selected when all or a significant part of the crown has been lost. If the break is high enough in the tree that only a small portion of the tree is lost, select “Primary Branch Broken” under tree conditions instead.
- Alive Fallen: The main stem is perpendicular to the ground.
- Dead: Tree has died since last measurement. If this is the first time a tree has been measured do not record it as dead, as it should not be part of the study. Rather just mark it as removed from study and note that it died before it could be measured for the first time.
- Missing: You cannot find this tree at all.
- Removed from Study: Tree is no longer part of study. If a tree is on the edge of the plot it may have been wrongly included during setup (outside of plot) and this is discovered during measurement.
- Downgraded to sapling: Plant no longer meets the requirements for a tree, but meets the requirements to be a sapling. Clarify the circumstances by making a comment in the notes section. Do not remove the tree tag.
- Downgraded to seedling: Plant no longer meets the requirements for a tree, but meets the requirements to be a seedling. Clarify the circumstances by making a comment in the notes section. Do not remove the tree tag.

Crown Class

Crown class refers to the position and height of the canopy compared to its neighbors and how much sunlight it receives (Figure 6). This information can be helpful in understanding growth rates and tree mortality. The crown classes are:

- 1. Open-grown: crown has received full sunlight from above and all sides through most of its life, particularly during early development.
- 2. Dominant: crown extends above canopy, receiving full light from above and some light from sides. Taller than the average tree in stand and has well-developed crown.
- 3. Co-dominant: crown at the general level of the canopy, receiving full light from above but little direct light from sides. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns.
- 4. Intermediate: tree is shorter than co-dominant trees but with a crown that extends into the general canopy. Crown receives little direct light from above and none from the side; tree has small crown and is very crowded from the sides.
- 5. Overtopped: crowns is entirely below the general level of the canopy and receives no direct sunlight.
- 6. Light Gap Exploiter: tree which receives full sunlight from above as it is in a light gap in the canopy, but is shorter than the surrounding canopy (added 2009).
- 7. Edge Tree: Tree below canopy height, but receives direct sunlight due to its position on the edge of the forest. (added 2009)

Figure 6. Illustration of crown classes from FIA protocols. Classes 6 and 7 not pictured.

Comments

Make any notes as directed in this SOP. Also, record any other observations of the tree that are unusual and may help explain mortality or other changes in the forest community. Do not attempt to write comments about each individual tree, only unusual observations should be noted.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Expanded explanation of equivalent diameter
- Matched sections in SOP with fields in database
- Improved text throughout
- Added light gap exploiter and edge tree to crown class categories.

Version 1.0 (January 2006)

Version of protocol used from 2006 to 2008.

SOP 8: Sapling and Shrub Measurements (March, 2009)

Version 2.0

Introduction

This SOP describes how to take measurements on saplings and shrubs. Saplings and shrubs are covered in the same SOP as they are both monitored only in the three microplots and nearly identical data is taken for each.

In order to distinguish between the three microplots they have been given names based on their azimuth: 60°, 180° and 300°.

What Is a Sapling?

A sapling is any tree with a dbh ≥ 1cm, but < 10 cm. Trees with a dbh ≥10 cm are monitored as trees, whereas those <1cm are monitored as seedlings. A tree can be originally monitored as a sapling, but later be monitored as a tree once it has a larger dbh.

What Is a Shrub?

A shrub is a woody plant species with a diameter at root crown ≥1cm and that typically has a growth form with many stems at breast height. In practice, a shrub is any woody species on the list of shrubs (Table 11), even if that particular individual has only a single main branch. Occasionally, as new species are found in the NCRN monitoring plots, additions are made to the list of shrubs.

Table 11. List of woody species monitored as shrubs.

Latin Name	Common Name	Year added
Alnus serrulata	hazel alder	2008
Castanea pumila	chinkapin	2008
Cornus amomum	silky dogwood	2008
Clethra spp.	sweet pepper bush	2006
Elaeagnus umbellata	autumn olive	2006
Euonymus alatus	burning bush	2006
Euonymus americanus	strawberry bush	2007
Euonymus atropurpureus	wahoo	2007
Gaylussacia frondosa	blue huckleberry	2007
Hamamelis virginiana	American witch-hazel	2006
Ilex verticillata	common winterberry	2006
Kalmia latifolia	mountain laurel	2006
Ligustrum obtusifolia	border privet	2006
Ligustrum ovalifolium	California privet	2008
Ligustrum vulgare	European privet	2008
Lindera benzoin	northern spicebush	2006
Lonicera maackii	Amur honeysuckle	2006
Lonicera morrowii	Morrow's honeysuckle	2008
Oplismenus undulatifolius	wavyleaf basket grass	2009
Rhododendron periclymenoides	pinxter flower	2007
Rhus copallina	shining sumac	2008
Rhus spp.	sumac	2006
Rosa carolina	Carolina rose	2008
Rubus argutus	sawtooth blackberry	2007
Sambucus canadensis	American black elderberry	2008
Sambucus pubens	red elderberry	2007
Staphylea trifolia	American bladdernut	2006
Symphoricarpos orbiculatus	coralberry	2006
Vaccinium corymbosum	highbush blueberry	2006
Vaccinium fuscatum	black highbush blueberry	2007
Vaccinium stamineum	deerberry	2006
Viburnum acerifolium	mapleleaf viburnum	2006
Viburnum dentatum	southern arrowwood	2006
Viburnum dilatatum	linden arrowwood	2008
Viburnum plicatum	Japanese snowball	2007
Viburnum prunifolium	blackhaw	2007
Viburnum sieboldii	Siebold's arrowwood	2007

Small woody plant species that could be confused with shrubs but are monitored as trees are listed in Table 12. Additionally, some small woody plant species that would commonly be called a shrub are monitored like a herbaceous plant in the quadrats (Table 12). These include shrubs which tend to be small and numerous, such as some *Vaccinium* species, that would often be missed in the microplots due to their small diameter. Also, shrubs that are vine-like and thorny, such as *Smilax* species, are monitored like herbaceous species as searching for the location where they root can result in trampling and can be painful for the monitoring crew.

Table 12. Woody plants that are sometimes considered shrubs but are monitored in other categories by the NCRN.

Latin Name	Common Name	Monitoring Category
Amelanchier spp.	serviceberry	tree
Asimina triloba	pawpaw	tree
Berberis spp.	barberry	herbaceous cover
Gaylussacia spp. (not *frondosa*)	huckleberry	herbaceous cover
Lonicera (not *maack, or morrowii*)	honeysuckle	herbaceous cover
Morus rubra	red mulberry	tree
Rosa spp. (not *carolina*)	rose	herbaceous cover
Smilax spp.	greenbrier	herbaceous cover
Vaccinium (not listed above)	blueberry	herbaceous cover

What if You Don't Know What It Is?

The monitoring crew may run into a situation where either they are unsure of the species identification of a plant or they are able to identify it but that species has not been monitored before. In those cases it may not be clear if the plant should be monitored as a sapling or a shrub. The crew should take data for the plant as both a sapling and as a shrub and a determination will be made later.

Sapling and Shrub Measurements

Tag Number

First locate the tag that is attached to the sapling or shrub. Select the corresponding plant in the database, or note down the tag number on the datasheet.

Occasionally you will encounter a sapling or shrub that does not already have a tag. This may be because the tag has been lost, the plant appeared dead when the plot was initially set up, the plant has grown since plot setup or the plant may have simply been missed. Record which microplot the plant occurs in and new tag on the plant. If it appears that the plant was previously marked but has lost its tag, note the new tag number under the old tag number if you can determine it.

Sapling/Shrub Identification

We are recording the species of each sapling and shrub so that we can relate species to habitat types and so we can determine if there are long term trends in the populations of individual plant species.

Record the scientific name of the plant. If the plant has already been identified, confirm the identification. If you find that it was identified incorrectly, note down the old ID, the new ID, your name, the date, and any notes that may be useful. If you cannot identify the plant, take a sample to identify as indicated in SOP 11.

Sapling Diameter at Breast Height

Diameter at breast height is used to calculate the basal area of each sapling. Basal area is an approximation of the area of the cross section of each tree at breast height. Basal area is used as a measure of the amount of living woody biomass in the forests and as a measure of importance of the various tree species. Measuring dbh will allow us to track trends in the basal area of the forests as a whole and of individual tree species.

Diameter at breast height is measured to 0.1 cm at 1.37 m from the ground. In most cases the tree will already be marked at dbh and the measurement should be taken at the marking. Diameter at breast height is measured in the same way as tree diameter is (see SOP 6). The only differences is that stems less than 1 cm diameter are not measured and are not used to determine equivalent diameter. These narrow stems are too difficult to measure accurately and make a very small contribution to basal area.

If a sapling bends or sags, measure the 1.37 along the length of the sapling. Do not try to find a spot that is 1.37m above the ground which may be much further along the stem.

Shrub Diameter at Root Crown

Diameter at root crown (drc) is used to measure the basal area of the shrub, much like dbh is used for trees and saplings. Furthermore, some shrubs may be relatively large, but have little biomass above breast height. The NCRN has tentative plans to use basal area calculated from drc as a measure of the amount of living woody biomass in the forests and as a measure of importance of the various shrub species. Measuring drc will allow us to track trends in the basal area of the forests as a whole and of individual shrub species.

The NCRN originally considered using dbh for shrubs, and a small amount of data was collected using dbh in 2006. However, it was decided that dbh was not a useful measure for shrubs. In many cases the bulk of the biomass of the shrub is below dbh and we were measuring just the tips of the branches. It is not clear what the relationship between dbh and biomass would be for such shrub species. Also, for species which tend to branch repeatedly low to the ground, collecting dbh on every branch was time consuming and it is difficult to be sure that every branch has been marked and measured.

Drc is measured to 0.1 cm just above the roots of the shrub. Otherwise, follow the same procedures as for dbh.

Status

Status indicates if the plant is alive, dead, or no longer part of the study and if it still standing. This information will be used to help understand causes of mortality and to track the reasons why plants are removed from the study. The status options are:

- Alive Standing: Plant is alive and is standing upright.
- Alive Leaning: Plant is leaning at more than 30° from vertical.
- Alive Broken: The main stem of the plant is broken off.
- Alive Fallen: The main stem is perpendicular to the ground.
- Dead: Plant has died since last measurement. If this is the first time a plant has been measured do not record it as dead, as it should not be part of the study. Rather just mark it as removed from study and note that it died before it could be measured for the first time.
- Missing: You cannot find this plant at all.

- Upgraded to Tree: Sapling has grown large enough that it is now monitored as a tree.
- Removed from Study: Plant is no longer part of study. If a plant is on the edge of the microplot it may have been wrongly included during setup (outside of plot) and this is discovered during measurement.
- Downgraded to seedling: Plant no longer meets the requirement to be a sapling, but does meet the requirements to be a seedling. Clarify the circumstances by making a comment in the notes section. Do not remove the tree tag.

Deer Browse
Record whether there is any evidence of deer browsing on the shrub or sapling. Stem tips that have been newly browsed by white-tailed deer typically have a dark brown band at the browse point and acuminate tips.

Comments
Make any notes as directed in this SOP. Also, record any other observations of the plant that are unusual and may help explain mortality or other changes in the forest community. Do not attempt to write comments about each individual plant, only unusual observations be noted.

Revision History

Version 2.0 (March, 2009)
- SOP reformatted for publication in NRR report series
- Matched sections in SOP with fields in database
- Improved text throughout

Version 1.0 (January 2006)
Version of protocol used from 2006 to 2008.

SOP 9: Herbaceous Plant and Seedling Measurements (March, 2009)

Version 2.0

Introduction

This SOP describes measurements of some herbaceous plant species and shrubs that are measured in the same manner as herbaceous plants, and seedlings of trees and shrubs.

Quadrat Location and Name

The herbaceous layer and seedlings are measured using twelve 2 × 0.5 m quadrats. Nine of the quadrats are laid out perpendicular to the three transects at 360°, 120°, and 240°. Three quadrats are placed along each transect, 20 cm to right when facing away from plot center. The lower corners of the quadrats should be at 3, 8, and 13 meters from plot center. The remaining three quadrats are placed in the center of the microplots used for measuring shrubs. The center of the quadrat should coincide with the microplot center, with the long axis of the quadrat pointing towards the plot center.

Each quadrat is given a name based on its locations. For quadrats along the transects, the name consists of the azimuth of the transect and the distance the quadrat is from plot center. For example, the quadrat that starts at 8 m along the 120° transect is referred to as 120°-8m. The quadrats that are in the microplots are named based solely on the microplot (e. g. 300°), without any reference to the distance.

PVC Quadrat Frame

To aid in taking measurements, the field crew will take a quadrat frame with them in the field. Quadrat frames are constructed out of ½ inch PVC. Each 2 × 0.5 m^2 quadrat frame is calibrated (painted in 10 cm sections) to make cover estimates easier. The quadrat is kept as separate poles for each side and then constructed around the vegetation in the field.

Level the quadrat if necessary by propping up the corners. When a quadrat is located on a steep slope the field crew should be positioned downhill from the quadrat to prevent sliding or falling into the quadrat.

Herbaceous Plant and Seedling Measures

Measuring Herbaceous Plants

Cover of select “herbaceous” species (Table 13) is measured in each quadrat. Some of the plant species measured under this portion of the monitoring program are actually woody shrubs, but they are measured in the same manner as the true herbaceous species. Additionally, some vines are measured under this SOP when they occur on the ground, and are also tallied when they grow on trees (SOP 7).

The NCRN does not monitor all herbaceous plant species, but rather a select group of species. Many of these species are exotic plants that are known to be invasive in the NCRN. There are many exotic species in the network that are not monitored as they are not invasive enough to be a concern. New exotic invasives are added to the list as conditions warrant.

Table 13. Herbaceous species monitored in quadrats.

Latin Name	Common Name	Reason to monitor	Year Added
Akebia quinata	chocolate vine	exotic invasive	2006
Alliaria petiolata	garlic mustard	exotic invasive	2006
Ampelopsis brevipedunculata	porcelain berry	exotic invasive	2006
Berberis thunbergii	Japanese barberry	exotic invasive	2006
Celastrus orbiculatus	oriental bittersweet	exotic invasive	2006
Centaurea biebersteinii	spotted knapweed	exotic invasive	2006
Cirsium arvense	Canada thistle	exotic invasive	2006
Clematis terniflora	sweet autumn clematis	exotic invasive	2006
Duchesnea indica	Indian strawberry	exotic invasive	2006
Euonymus fortunei	winter creeper	exotic invasive	2006
Glechoma hederacea	ground ivy	exotic invasive	2006
Hedera helix	English ivy	exotic invasive	2006
Hemerocallis fulva	orange day lily	exotic invasive	2006
Lespedeza cuneata	Chinese lespedeza	exotic invasive	2006
Liliaceae (family)	lily family	preferred by deer	2006
Lonicera japonica	Japanese honeysuckle	exotic invasive	2006
Lonicera spp.	honeysuckle	exotic invasive	2006
Lysimachia nummularia	creeping jenny	exotic invasive	2008
Microstegium vimineum	Japanese stiltgrass	exotic invasive	2006
Murdannia keisak	marsh dewflower	exotic invasive	2009
Oplismenus undulatifolius	wavyleaf basket grass	exotic invasive	2009
Orchidaceae (family)	orchids	preferred by deer	2008
Podophyllum peltatum	may apple	preferred by deer	2006
Polygonum caespitosum	Oriental ladysthumb	exotic invasive	2008
Polygonum cuspidatum	Japanese knotweed	exotic invasive	2006
Polygonum perfoliatum	mile-a-minute	exotic invasive	2006
Polygonum persicaria	Asiatic tearthumb	exotic invasive	2008
Pueraria montana	kudzu	exotic invasive	2006
Ranunculus ficaria	fig buttercup	exotic invasive	2006
Rosa multiflora	multiflora rose	exotic invasive	2006
Rubus phoenicolasius	wineberry	exotic invasive	2006
Smilax glauca	cat greenbrier	preferred by deer	2008
Smilax rotundifolia	common greenbrier	preferred by deer	2008
Smilax tamnoides	bristly greenbrier	preferred by deer	2008
Toxicodendron radicans	poison ivy	determine extent	2006
Vaccinium spp.	blueberries	preferred by deer	2006
Viburnum dilatatum	Linden arrowwood	exotic invasive	2006
Vinca minor	common periwinkle	exotic invasive	2006
Wisteria sinensis	Chinese wisteria	exotic invasive	2006

We are also monitoring herbaceous plants that are generally considered to be highly sought after by deer (Table 13). This data will be used to help assess deer impact on the parks. Some species (Ferns, Liliaceae and Orchidaceae) are monitored as a group rather than as individual species as they are rare in general. If possible, indicate which specific species were found in the "Comments" If you cannot identify the species indicate that as well. In 2006 and 2007 "*Smilax* spp." were monitored as a group. In 2008, "*Smilax* spp.' was removed from the list and replaced with the three individual species as they were fairly easy to separate. Poison ivy is also monitored in the quadrats in order to determine how common it is across the parks and to warn future field crews which plots are heavily infested.

Only estimate foliar cover on plants or portions of plants that fall inside the quadrat frame and less than 2 m above the ground. For each plant, cover is based on a vertically-projected polygon described by the outline of each plant, ignoring any normal spaces occurring between the leaves of a plant (Figure 7, Daubenmire, 1959). This best reflects the plant's above-ground zone of dominance.

The only exception is for species represented by plants that are rooted in the quadrat, but have canopies that do not cover the quadrat or that are more than 2m above the ground; estimate cover for these species based on their basal area. That is, estimate what percent to the plot is covered by the base of the woody stem that is in the plot.

Base percent cover estimates on the current years' growth, by including living, damaged, and dead material from the current year. Record the percent cover present at the time of the plot visit. Do not adjust the percent for the time of year during which the visit was made (i.e., for immature or wilted plants). Sparse plants can be difficult to assess, but follow the polygon rule unless it is obvious that the plant(s) have been trampled or otherwise recently disturbed and would naturally stand more upright.

Overlap of plants of the same species is ignored. Visually group the plants in a species together into a percent cover. Familiarize yourself with what certain cover estimates (e.g., 1%, 10%, 15%, etc.) look like and use them as reference sizes. There will often be overlap of plants of different species. Therefore, your total cover for a quadrat may exceed 100%.

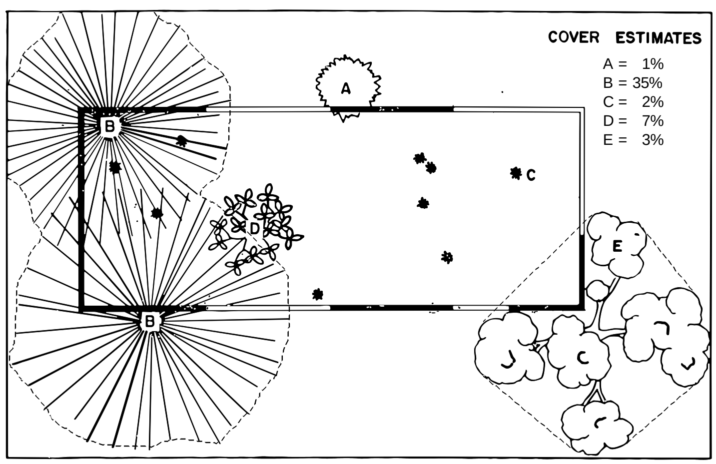

Figure 7. Illustration of cover method based on polygon outline of plants using a rectangular "Daubenmire plot". Notice that plant E has no foliage over the plot but its outline does cover a portion of the plot. Adapted from Daubenmire (1959), FIA (2004).

Unlike some other forest monitoring protocols, herbaceous cover is not measured by placing it in a category (e.g. <5%, 5-10% etc.). Ideally, the data collected from this protocol will be comparable to data that already exists for the parks and data that is collected in other nearby areas, such as other I&M networks, or other state or federal agencies. There is no universally agreed upon set of categories to use for this type of study. Therefore, in this protocol the data is recorded as a raw percentage and will be placed into categories later. The categories used in any particular analysis will be determined on a case by case basis, based on how the data will be used and other data it might be compared to.

Measuring Seedlings
In each quadrat, record the scientific name of each tree and shrub seedling. Tree seedlings are woody plants <1 cm dbh and ≥15 cm tall. If the seedling is less than 15cm tall do not count it. Only count seedlings rooted in the quadrat.

Quadrat Floor Conditions
"Quadrat floor conditions" are anything that can occupy part of a quadrat and excludes herbaceous vegetation. The categories are: trees, rocks, CWD (coarse woody debris) and "other". Estimate the % of the quadrat that each of these conditions covers to either the nearest 1% if the cover is less than 10%, or to the nearest 5% if the cover is over 10%.

The "trees" category only includes the area covered by the stem/trunk of woody plants and does not include cover of the canopy. This category includes standing dead as well as living trees. CWD includes any wood laying on the soil with a diameter ≥ 7.5 cm. "Other" can include any other object (such as trash). If the cover of other is greater than 0, note in the comments section what object is being measured.

Vegetation Cover
"Vegetation cover" is a measure of several types of vegetation that can occur in the quadrat. This data is monitored to help determine if there are trends in understory cover of these groups over time. These categories are: grasses, sedges, herbs, ferns and bryophytes. Estimate the % of the quadrat that each of these conditions covers to either the nearest 1% if the cover is less than 10%, or to the nearest 5% if the cover is over 10%.

Comments
Record anything unusual about the plants or measurements.

References

Daubenmire, R. F. 1959. A canopy-coverage method. Northwest Science **33**:43-64.

Forest Inventory and Analysis [FIA]. 2004. Forest Inventory and Analysis program background. U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis program, Washington, DC. http://fia.fs.fed.us/. [accessed December 1, 2004]

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Matched sections in SOP with fields in database
- Improved text throughout
- Added invasive species

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2008.

SOP 10: Coarse Woody Debris (March, 2009)

Version 2.0

Introduction

This SOP describes the methods to measure coarse woody debris on the plots along the three transects. Coarse woody debris (CWD) is an important habitat for many animal and microbial species, and a net loss of coarse woody debris can result in a reduction of biodiversity.

What is Coarse Woody Debris?

Coarse woody debris is large pieces of dead wood. The dead wood can be from any woody plant and can be from a branch or a main stem. For the purposes of this protocol, we are defining it as dead wood which is lying on the ground or within 2m of the ground, and has a diameter ≥7.5 cm and a length ≥1m. The diameter measurement only applied to the point where the wood crossed the transect. Dead trees that are still standing are not counted. If a dead tree is leaning more than 45° from vertical, it is counted as CWD. To qualify as CWD, a piece must retain some structural integrity. Very decomposed logs that are slightly elevated 'humps' on the ground are not tallied as CWD.

What is done with the measurements?

As described below you will measure the diameter of coarse woody debris along the transects. This data is used to calculate the volume of CWD in the plot in m^3/ha. This is calculated with the following formula:

$$Volume\left(\frac{m^3}{ha}\right)=\frac{\pi^2\sum_{i=1}^{n}d_i^2}{8L}$$

where *d* is the diameter in cm, *n* is the number of intersections, and *L* is the total length of the transects (van Wagner, 1968). In the NCRN, the total length of the transects is 45m, so the equation reduces to:

$$Volume\left(\frac{m^3}{ha}\right)=0.02742\left(\sum_{i=1}^{n}d_i^2\right)$$

Measuring Coarse Woody Debris

Transects

CWD is measured along the three transects that are at azimuths 120°, 240° and 360°. Each transect is 15m long. Occasionally you will find that the marker at the end of the transect is slightly closer or farther than 15m. In these cases you should measure CWD for 15m regardless of where the transect marker is. Unlike plot setup, the 15m is measured along the slope rather than horizontal distance. If the azimuth of the transect marker is wrong, note it down in the comments section, but measure the CWD along the azimuth of the marker.

Measuring Diameter
Most CWD will be laying on the ground. To be tallied by this protocol, the point of intersection between the transect and the central longitudinal axis of the piece must occur on or above the ground, but not more than 2m above the ground. The piece must be ≥ 1 m long. The piece must also meet the ≥7.5 cm diameter requirement where it intersects the transect. If the piece is <7.5 cm diameter at the transect but has a large enough diameter elsewhere, it does not count.

Occasionally a piece intersects a transect line more than once or intersects two transect lines. In these cases tally the piece each time it intersects. The estimate for CWD is based on the number and size of the intercepts of the transect with CWD, not on a count of pieces of CWD.

In the event that a piece of wood is at the exact center of the plot where the three transects meet, tally that piece only once, on the 360° transect.

The diameter of each piece is measured to the nearest 0.1 cm where the transect intersects the longitudinal center of the piece. Measure the diameter perpendicular to the length of the piece, not along the transect. Diameter of CWD is typically measured by using a dbh tape, or by holding a steel tape or ruler above the log or by using calipers. Chose whichever method works best given the situation, but try to avoid disturbing the log too much. Do not lift up large pieces of wood in order to put a dbh tape around them.

For pieces that are not round in cross-section because of missing chunks or "settling" due to decay, measure the diameter in two directions and average, if this is possible. Estimate the longest and shortest axis of the cross-section (Figure 8) and record the average value.

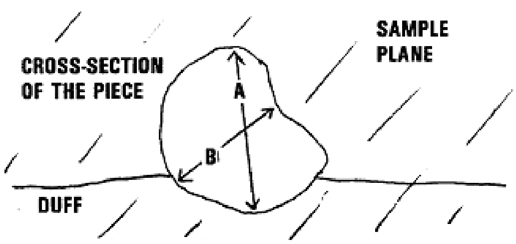

Figure 8. Measuring diameter of deformed CWD.

Decay Class
Record the decay class of each piece on a five point scale (Table 14). The scale was originally developed for Douglas-fir in the Pacific Northwest (Fogel et al 1973, Maser et al 1979). The table presents the scale as modified for eastern forests dominated by hardwood trees (Pyle and Brown 1998, Rubino and McCarthy 2003). In practice a single piece of wood can exhibit a variety of decay classes along its length. Record the decay class that best fits the point where the wood intersects the transect. A single piece of wood may not exhibit every characteristic for a given decay class, so choose the class that best fits.

Table 14. Decay classes for coarse woody debris.

Decay Class	1	2	3	4	5
Bark	Firmly attached	Not firmly attached	Absent	Absent	Absent
Color	Fresh, not weathered	Weathered	Bleached or brown depending on type of rot	Bleached or brown depending on type of rot	Bleached or brown depending on type of rot
Surface	Bark	Hard wood or decaying bark	Soft wood	Spongy or chunky powdered wood	Powdered wood
Consistency	Solid	Solid	Firm, but will compress or shred	Not a solid piece, but some solid pieces remain, will crush	Powdery or chunky
Shape	Unchanged	Unchanged	Unchanged	May be oval	Flattened
Small Branches	Present	May be present	Absent	Absent	Absent
Moss	Absent	Absent	Absent	Present	Present
Sapwood	Sound	May be decayed or sound	Decayed	Very decayed	Not discernable

Species
If you know what species or genus the wood was when it was alive record it. In general, well decayed wood will be difficult to identity, but newly fallen branches may have leaves or bark that can be identified. Occasionally trees that were being monitored will fall and be tallied as CWD. In that case record the tree species and in the comments note the tag number from the tree. Do not remove the tag.

Hollow
Record if the piece is hollow. A piece is considered hollow if a cavity extends at least 0.5 m along the central longitudinal axis of the piece, and the cavity entrance is at least 1/4 the diameter of the piece.

Transect Monitored
After the transect has been searched for coarse wood debris, check the box indicating that the transect has been monitored. Do this even if no CWD has been found. This will allow us to ensure that transects with no data have actually be monitored.

Comments
Record in the comments any unusual observations.

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Pyle, C. and M. M. Brown. 1998. A rapid system of decay classification for hardwood logs of the eastern deciduous forest floor. Journal of the Torrey Botanical Society **125**: 237-245.

Rubino, D. L., and B. C. McCarthy. 2003. Evaluation of coarse woody debris and forest vegetation across topographic gradients in a southern Ohio forest. Forest Ecology and Management **183**:221-238.

Van Wagner, C. E. 1968. The line intersect method in forest fuel sampling. Forest Science **14**:20-26

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series.
- Matched sections in SOP with fields in database.
- The characteristic on the coarse woody debris decay table were updated to better reflect eastern deciduous forests.
- Improved text throughout.

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2008.

SOP 11: Collection of Unknown Plant Species (March, 2009)

Version 2.0

Introduction

This Standard Operating Procedure (SOP) describes the procedure for collecting, pressing, storing, and processing unknown plants. For the procedure used for the collection of voucher specimens, refer to the data management plan SOP on vouchers.

What Should be Collected?

Specimens of all plants that cannot be confidently identified to species should be collected off the plot, if possible, labeled, pressed and dried for subsequent identification by the field botanist or a cooperating herbarium.

Methods

When you encounter a plant you do not recognize and you cannot identify it quickly using field guides, collect it. Find a specimen to collect that is off the plot, if possible. Make sure the collection is as representative as possible, including leaves, flowers, fruits, etc.

Plants can be stored and carried from plots in paper bags, and kept cool for later keying. Crispy plants can be re-hydrated in a zip-lock bag. If a plant cannot be identified within a few hours of returning from the field, they must be pressed and dried with an identifying label.

Pressing Plants

Collected plants will be pressed and stored in a plant press until they can be identified. Plant presses contain blotters (thick blotting paper) and ventilators (corrugated cardboard) and newspaper. Begin to fill your press on one side, laying a single ventilator on one of the press frame pieces. Lay a single blotter on top of the ventilator, and then open a single fold of newsprint and place one side on the blotter. Put only one plant in the folded newsprint. Bend the stem in a v-, z- or w-arrangement to fit it on a single newsprint page. Larger specimens may need several sheets, but usually you can fit all essential plant parts in a single folded section. Plants can be trimmed to reduce bulk, as long as the diagnostic parts are included, such as stem sections, petioles, and branch bases. Arrange the specimens so some upper and some lower surfaces are exposed. Flower parts should be visible as well, including stamens, pistils, sepals and petals. You can tear or cut small strips of newsprint and wet them with water to use to hold leaves and flowers in place. This will add drying time, but the quality of the pressed specimen is well worth it. Before you close the newsprint fold, be sure to add the label.

The usual arrangement in the press is ventilator-blotter-newsprint (with plant)-blotter-ventilator-blotter-newsprint (and next plant)-blotter, and so on. If you have large or succulent plants, they may be sectioned to reduce bulk.

When you have finished placing your specimens in the press, place the second part of the frame on top of your last ventilator and tighten the straps firmly. It works best if the straps are fastened from opposing directions. To help expedite the drying of plants, keep in mind that water vapor rises. If you prop the press so that the “tubes” of the corrugated cardboard run up and down, the plants will dry faster.

Collection Notes

Include the following notes with your plant collection:

- Plot Code
- Date
- Family or genus, if known
- Names of field crew
- Any useful information about the plant, such as habitat or observations of leaves or other parts that were too high to reach.
- In the unlikely event that more than one unknown plant is found on one day in a particular plot, give each collection a unique code that includes the plot code (e.g. ANTI-0001 a, ANTI-0001 b, etc).

Database Notes

Record the species as unknown in the tablet. It can either be recorded as completely unknown or as an unknown species of a known family or genus. Additional notes should be included in the notes section of the database related to that particular plant. Indicate that a collection was made and its unique collection code if one is needed. Included any information that would help with identification. Also include any information that would aid in relocating the plant from which the collection was made.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Improved text throughout

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2008.

SOP 12: Data Entry and Verification (March, 2009)

Version 2.0

Introduction
The purpose of this SOP is to outline the processes that should be followed when entering data into the forest vegetation monitoring database. Also described are the steps that should be taken to verify and validate data once it is in the database.

Definitions
Verification – Pertains mainly to data that are entered from paper data sheets. It involves ensuring that the information entered into the database is the same as the data on the field data sheets.

Validation – Pertains to field data collected on paper field forms as well as data collected electronically on field computers. Validation involves checking to make sure that the data make sense. For example, if a dbh of -9000cm is entered it is fairly apparent that that value is incorrect.

Procedures and General Requirements
The primary method of data collection for forest vegetation monitoring data will be through the use of tablet PCs deployed with the full MS Access version of the forest vegetation monitoring database. Field crews are required to carry paper field forms with them as a contingency in case the field computers are not functioning. Therefore, this document will provide guidance for transferring data from field computers and enter raw data from data sheets.

Entering Data on Field Computers
Data Entry: When using field computers data is entered directly into a project database while it is being collected in the field. The advantages to this are numerous and include:
- The database can be designed to require the entry of essential information such as date and location.
- Validation rules can be incorporated directly into the database that will alert field crews if an inappropriate value is entered (e.g. a negative dbh).
- The availability of defined pick lists for the user to choose from ensuring that only certain, pre-defined parameters can be entered. The use of such lists also eliminates the possibility of typos and misspellings.
- The data entry step that would normally take place when using paper field forms is eliminated. All data entry takes place in the field making the use of field computers a much more efficient means of collecting data. Also, eliminating the data entry step from paper to computer reduces the chances of data entry errors into the database.

If two field computers are used then one field computer is dedicated to the crew member collecting data from the herbaceous quadrats and from the coarse woody debris transects. This computer should not be used to collect data from any other section of the plot unless absolutely necessary and should be designated as “Tablet #2 (secondary)”. The other field computer should be used by the remaining crew member(s) to collect data from the remaining parts of the plot and should be designated as “Tablet #1 (primary)”.

Data Verification: The data verification is process is much less of an issue when field computers are used for collecting data as there are no paper data sheets to compare with data in a database. Even though these devices help reduce the chance for errors, it is still possible to enter erroneous data (e.g. selecting the wrong species from the drop down list). Accordingly, there are certain verification steps that should be taken to ensure proper data entry.

Prior to leaving a field site following data collection, field crews should review the data collected on the field computer(s) to try and catch any data entry errors. Someone other than the person entering the data in the field should check the data.

Data Transfer: The field crew, upon returning to the office, will work with the data manager to transfer the data from the tablets to the NCRN file server. The database file(s) containing the new field data should be renamed and tagged with a specific date identifier referring to when the data was collected. If one field computer is used, the data file should be tagged with a suffix of “single”. If two field computers are used, the data files should be tagged with a suffix of “primary” or “secondary” designating which tablet the data was collected on.

For example, a file name could be “NCRN_Forest_Veg_DB_be 2007-06-07 Primary.mdb”, where the first portion of the name indicated the protocol database name, followed by the date and finally the tablet function. The renamed file(s) should be transferred to a folder on a dedicated flash drive named “Field Data YYYY-MM-DD”, where YYYY-MM-DD identifies the date that the data was collected. The renamed file(s) should then be transferred to the file server and placed in the forest vegetation monitoring folder under Database\Field Data. No data should be stored on the field computers for more than the length of a field trip. The NCRN data manager will help you with renaming and moving the files.

The data manager will make sure the field data are incorporated into the monitoring database using the importing and appending utilities. These utilities will ensure that the proper data from each tablet dataset are imported and appended to the proper data tables in the main working data file.

After importing and appending new data to the master forest monitoring database data management staff review the database for any obvious import errors. Data management staff produce event summary reports from the database that all members of the field crew must review for accuracy and initial once completed.

Once successful data import has been confirmed, the field database(s) copied from the field computers should be moved to the “Field Data Import Complete” folder. It is important to maintain these “field” data sets as they are the raw field data (akin to a paper field data sheet).

Entering Data from Paper Field Forms

Data Entry: Upon returning from the field with paper data sheets, all data sheets are to be copied and the copies placed in the proper folder in the fire-proof cabinet. Originals are taken back to the offices where the data are entered.

Data collected on paper data sheets should be entered into the project database within one week of collection. This will allow information about the sampling trip to remain fresh in the minds of the field crew in case of a question. Data should be entered by someone on the crew that collected it. Ideally, more than one member of the field crew should be involved during data entry. This will allow for proper interpretation of notes on the data sheet as well as increase the possibility that errors on the data sheet will be caught during data entry. If any mistakes are discovered on the data sheets the data should be entered into the database correctly and a notation made on the data sheet. If any questions arise during data entry, the data entry personnel should make a note of any uncertainties on the data sheet as well as in the database record.

Upon the completion of data entry, personnel should indicate who entered the data and the date it was entered in the database. The data sheets should also be dated and initialed by the person(s) entering the data.

Data Verification: Once the data for a specific sampling event has been entered, the data must be verified. Someone other than the person(s) who entered the data should review the data that was entered and compare it to the data sheets. Ideally this should be someone on the field crew but does not have to be. If errors are found, the record should be corrected and a notation made in the database as well as on the data sheet as to who updated the record and when it was updated. The verifier should indicate in the database as well as on the data sheets that they verified the data and the date on which the data were verified.

Upon completing the data verification steps, the data sheets should be stored in a safe location off-site. Data sheets will be permanently archived at the Regional Museum Resource Center after five years. Copies will still be maintained in the fire-proof storage cabinet.

Data Validation

Regardless of whether field data are collected on paper data sheets or on field computers, all data must be validated. Data validation involves making sure that the data collected makes sense. Many of these checks can be incorporated into project database regardless of whether they are deployed on field computers or sit on desktop computers. The benefit of having validation checks incorporated into field databases in the field is that questionable data can immediately be flagged, checked and if need be corrected. It is important to remember that simply because data seem unusual or are identified as outliers does not make them incorrect. Before deleting or changing any such errors always double check to be sure that the information is incorrect.

Responsibilities

Data Manager

- Ensure that all members of the field crew are aware of the procedures outlining how data should be entered into project database, verified and validated.

- Make sure that field crews enter/upload the field data in a timely fashion.
- Ensure that data undergo the proper QA/QC procedures.
- Provide training and/or assistance with project databases.
- Develop database tools to assist with data entry and data QA/QC procedures.
- Archive data sheets and field data sheets

Field Crews

- Follow all data collection procedures.
- Enter/upload data into project databases in a timely fashion.
- Conduct data verification and validation checks.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Improved text throughout

Version 1.1(July 2007)

Updated data transfer procedures.

Version 1.0 (January 2006)

Version of protocol used from 2006 to 2007.

SOP 13: Analysis and Reporting (March, 2009)

Version 1.0

Introduction

The purpose of this SOP is to describe the procedures used for analysis and reporting. It is anticipated that the analysis and reporting will change significantly as multiple measurements of the plots are made. This SOP will focus solely on the analysis and reporting already taking place and does not describe future plans that require more data than currently available.

Reporting Schedule

Annual reports will be prepared in the fall and winter after each field season. Preparation of the reports can begin after all data has been collected, verified and validated. Occasionally the field crew may need to revisit a plot to collect data that was missed on the first visit, do not prepare the report until this has been completed.

In addition to the annual report, a longer report will be prepared after each 4 year panel. The longer report will summarize the results from all plots being monitored.

Annual Report Contents

The purpose of the annual report will be to summarize the findings for each field season. As only 25% of the plots are sampled each year, statistical analysis will be very limited, at least for the initial years. The report will contain summaries of the data both at the regional and the park scale. The report will include all three of the vital signs covered in this protocol. Reports that have been prepared in previous years should be used as a guide to prepare future reports.

Locations of Plots

Each year a map should be provided that indicates the plot locations in each park. Locations that were considered and ultimately rejected should also be shown. The exact coordinates of each plot should not be included as the reports are public information. The plot locations are provided in the annual permit requests to the parks, and are also available to the parks upon request.

Summary Data: Forest Communities

The report will provide summary data at both the regional and park levels. The report should include the following information at the network, park and plot levels:

- Tree density, basal area/ha and species richness.
- Sapling density, basal area/ha and species richness.
- Tree seedling density.
- Shrub density, basal area/ha and species richness.
- Shrub seedling density.
- Volume of coarse woody debris per hectare (at regional and park levels only).

The following information should be summarized on a per species basis at the network and park levels:

- Tree species identification, number of individuals and basal area.

- Sapling species identification, number of individuals and basal area.
- Tree seedling species identification and number of individuals.
- Shrub species identification, number of individuals and basal area.
- Shrub seedling species identification, number of individuals.

Summary Data: Forest Pests and Diseases
Forest pest and disease information will be summarized both regionally and by park. Summary information should include which pests or disease were found, where they were found, and which tree species were affected.

Summary Data: Exotic Plant Species
Data on exotic trees and shrubs will be summarized as part of the forest community summaries outlined above.

The following information should be presented for vines:
- Number of trees with vines, and number of trees with vines in the crown at the network, park and plot level.
- Vine identification, number of trees it is found on and number of times it is found on a tree with vines in the crown at the network and park level.
- For each tree species, the number of individuals with vines and the number with vines in their crowns at the network and park level.

The following information should be presented for exotic herbaceous species on trees:
- The number of plots with exotic herbaceous species and the number of quadrats with exotics at the network and park levels.
- The identification of exotic herbaceous species, the number of plots they occur on and the mean % cover they have on plots where they occur at the network and park levels.

Report Formatting
Annual reports will be published in the National Park Service's Natural Resource Technical Report Series. Formatting will follow current guidelines for that series.

Annual Report Peer Review
The Regional Inventory and Monitoring Coordinator for the NCRN will determine the level of peer review needed for annual reports. In general it is anticipated that routine data summaries will not require external peer review, but more intensive analysis may merit outside review.

Automation of Reporting
When possible, preparation of the data for the annual reports should be automated in the forest monitoring database. Automating summaries which will be prepared annually will speed up the process of preparing the reports and will reduce the opportunities for human error when the data is exported and summarized in a different software package. Automating the summaries will also help to make the reports more consistent year to year, even when there is turnover in the staff.

Revision History

Version1.0 (March, 2009)

Original version of the protocol, in use since 2005, but formalized as an SOP in November, 2008

SOP 14: Data Management (March, 2009)

Version 2.0

Introduction

The purpose of this SOP is to define the data management guidelines and procedures that apply to the forest vegetation monitoring protocol. This document focuses primarily on the procedures involved with the storage and documenting of data collected for the Forest Vegetation Monitoring vital sign.

Procedures and General Requirements

The I&M Program strives to provide accurate data that will be useful to park managers and the scientific community to help inform management decisions both now and far into the future. In order to ensure that the data collected and information products produced achieve this goal, data and products must be reviewed for accuracy, documented completely, and stored securely.

Reviewing Data (QA/QC)

Refer to SOP 12: Data Entry and Verification

Data Documentation (Metadata)

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which is defined as structured information about the content, quality, condition, and other characteristics of a data set. Basically speaking, the 'who', 'what', 'when', 'where', 'why' and 'how' of the data set. In addition, metadata include information about data format, collection and analysis methods, access/use constraints, and distribution. Metadata provide the means to catalog data sets, within intranet and internet systems, making their associated data sets available to a broad range of potential users.

Requirements: Metadata should be generated/updated for all electronic data files produced for the vegetation monitoring protocol. This includes spatial and non-spatial data. If products include both a GIS layer and a database file, each product needs an XML metadata file associated with it.

Metadata should be updated annually once the field season has been completed and data sets have been certified as accurate and complete. It is important to update:

- Personnel involved (i.e. members of the field crew)
- Time frame of the project
- Does the data set contain sensitive information? (e.g. was an endangered plant species found at a plot during the surveys?)
- Did methodologies or protocols change during the field season? (e.g. did the protocol for measuring shrubs or saplings change?)
    - If protocols did change, make sure to cross-reference the correct version of the protocol document.
- Did any of the data analysis procedures change?

Tools for Metadata Generation: A number of tools exist to facilitate the generation of metadata. Project staff members are encouraged to use tools such as the NPS Metadata Tools and Editor which is an application developed by the national I&M Program to assist with creating and editing NPS metadata files. This tool can function as a stand-alone application or as part of ESRI's ArcCatalog application. A metadata template for this project already exists and has been populated with much of the basic project information. If project staff choose to use the Metadata Editor the data manager can provide training and support.

For those not comfortable using the Metadata Editor a metadata questionnaire will be provided to staff for completion. Once the metadata questionnaire is complete, data management staff will update the XML metadata template. A copy of the questionnaire can be obtained by contacting the data manager.

Note: No annual data set will be considered final unless it associated with updated (current) metadata.

For more detailed information about generating metadata and network metadata requirements please refer to the Network's Metadata SOP. (http://science.nature.nps.gov/im/units/ncrn/products/guideline_docs/SOP-Metadata_Ver_2.0.pdf)

Network Data Storage and Archiving

All protocol materials are maintained on the NCRN data server under the following directory:

T:\I&M\MONITORING\Forest_Vegetation\

Protocol and SOPs: All currently active protocols and SOPs will be maintained in the 'Protocol' directory. Copies of the currently active protocol and SOPs will also be stored under the appropriate 'ARCHIVE' folder in case the 'Active' file is inadvertently altered or deleted.

Field Data: All field data will remain under the 'MONITORING' data folder until the field season has been completed and data have been certified and documented at which time the data manager will archive the annual data products. Archived products can be found here:

T:\I&M\Archive\Monitoring_ARCHIVE\Forest_Vegetation

Responsibilities

Data Manager

- Ensure that all members of the field crew are aware of the procedures outlining how data should be entered into project database, verified and validated.
- Ensure that data undergo the proper QA/QC procedures.
- Make sure that all data sets are associated with updated metadata.
- Archive data sheets and field data sheets.

Field Crews

- Conduct data verification and validation checks.
- Update annual metadata files.

Revision History

Version 2.0 (March, 2009)

- SOP reformatted for publication in NRR report series
- Improved text throughout

Version 1.0 (January, 2006)

Version of protocol used from 2006 to 2007.

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National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov